Sensing in Agriculture

International Symposium on Sensing in Agriculture
In Memory of Dahlia Greidinger

21-24 February 2011 Technion, Haifa, Israel

Abstract Book

Edited by:
Maxim Shoshany & Avi Shaviv

AGRI-SENSING 2011

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WELCOME TO AGRI-SENSING 2011!

The increased demand for food and the depletion of natural resources necessitates efficient and environmentally friendly agricultural practices. Sensing systems provide a non-invasive means of monitoring crop conditions and controlling the amount of resources supplied to the plants to achieve sustainable production. The aim of this symposium is to review research and development in the fields of remote and direct sensing and their future operational support in assuring sustainable production. Current technologies offer new opportunities for extracting dynamic information regarding plant and soil fertility status and assessment of water, nutrients, and other agrochemical inputs. The use of this information to facilitate efficient responses to situations evolving in the field, in the orchard, and in rangelands requires sophisticated algorithms, models, and data-processing systems. This symposium will look at sensing and information-processing tools and their integration within management systems. It will facilitate a meeting point between experts from the diverse fields of sensor systems & signal processing and from different fields in agriculture (plant physiology, soil physics/conservation, soil fertility, irrigation, plant protection, and more).

More than **70 international and Israeli experts** will participate in the conference as speakers. Keynote and invited speakers will review state-of-the-art developments in sensing in agriculture technologies. New models and algorithms alongside empirical information extracted from research in the field will be reported in 7 themes: Precision Agriculture, Field Crops, Orchards, Fertilizers and Fertility, Soil and Water Conservation, Sensing and Control Systems, and Rangelands.

All of this could not be realized without the generous support and encouragement of the Greidinger Family in commemoration of Dahlia Greidinger who as a scientist was devoted to the development of environmentally friendly fertilization. We are most grateful for the opportunity provided by the Dahlia Greidinger Fund to gather a group of such excellent senior and young scientists from 12 countries. We extend our deep thanks to the Technion, and to the Faculty of Civil and Environmental Engineering and the Grand Water Research Institute for providing the home and infrastructure for the research and for the Dahlia Greidinger Conferences.

We are very thankful to our co-sponsors: the Grand Water Research Institute, ICL Fertilizers, Fertilizers and Chemicals Ltd, the Norman and Asher Space Research Institute, the Moshe Yanai Life Sciences Grant Scheme (Technion), and the Soil Erosion Research Station (Ministry of Agriculture) who assisted in making the symposium program attractive to so many researchers, professionals, and students.

We thank all the people who have taken responsibility in organizing this important event: the Organizing Committee, the Theme Heads, the Conference Secretary Davida Kozer, our many other assistants, especially Yoav Doytscher and Adi Lavee.

FINALLY, WE WISH A MOST FRUITFULL AND ENJOYABLE CONFERENCE TO ALL THE PARTICIPANTS JOINING US.

Maxim Shoshany and Avi Shaviv

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Victor Alchanatis & Yafit Cohen

INTEGRATING PROXIMAL SENSING AND GEOSTATISTICS TO DELINEATE MANAGEMENT ZONES

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Fundamental to the philosophy of Precision Agriculture is the concept of matching inputs to needs. Recent research in precision agriculture has focused on use of Management Zones which are field areas characterised by homogeneous attributes in landscape and soil conditions. There are several methods for delineating management zones, depending on the sources of information and the data processing techniques used. Geo-electrical sensors are often used as auxiliary variables with sparse direct measurements to estimate soil properties. However, using a single sensor may sometimes prove problematic, whereas the complementary use of sensors can compensate such weaknesses. A multi-sensor platform can actually discriminate soils that give similar outputs to one sensor. Traditional clustering techniques, commonly used to associate spatial data, do not account for spatial correlation between observations and gradual change, both from one class to another and within any one class. Differently, geostatistics treats variables as continua in a joint attribute and geographic space. Therefore, in geostatistical applications clusters are unnecessary, nevertheless in precision farming it may be sensible to divide the field into a restricted number of practical management zones. It then needs to develop an algorithm of clustering that is also spatially constrained, in order to ensure spatial contiguity. The application of multivariate geostatistical algorithm allows researchers to better account for the continuous variability in natural phenomena over different spatial scales. The objective of the presentation is to show the potential of multivariate geostatistics to create management zones in the perspective of Precision Agriculture by integrating field data from different types of sensors (EMI, γ sensors, GPR, TDR, DGPS). Some study cases will be showed taken from the experience of the author.

REMOTE AND PROXIMAL SENSING DATA FUSION TO EVALUTE SOIL IMPACT ON VEGETATION

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Physical and textural soil properties have an important impact on the crop response and infer on the agricultural production in both quantitative and qualitative terms. Therefore, the spatial heterogeneity assessment of soil properties represents a crucial issue in improving agricultural management, because it may reveal the spatial variability and orientate the farmers in a rational use of natural resources.

There is a growing demand for rapid, relatively cheap and non-invasive acquisition of fine-scale information on soil and vegetation for site-specific assessment. Data acquisition methods based on proximal and remote sensing are being considered to complement conventional soil survey for estimation of soil and plant properties.

Electromagnetic induction methods (EMI) measure the soil apparent electrical conductivity (EC_a), a valuable geophysical measurement in agriculture for characterizing soil spatial variability which can be intensively recorded in an easy and inexpensive way. EC_a is usually related to various physical and chemical properties, such as soil salinity, clay content and mineralogy, organic matter and water content and so it can be used to improve the estimation of soil variables.

The remotely sensed data for monitoring crop properties play an important role in environmental and agricultural applications. Remote sensing with high-resolution multispectral satellite doesn't provide satisfactory information on the soil matrix, but it provides a detection for vegetative analyses that can reveal plant type, age, health and diversity.

Spatial analysis technique are needed to integrate different types of data, coming from both proximal and remote sensing, in order to delineate within-field areas to be submitted to differential management (management zones).

This paper proposes an approach of integrating EMI and remote sensing to for management zones delineation based on a combination of multivariate geostatistics with non-parametric density algorithm of clustering.

A 1.5 ha arable field located in south-east Italy was densely surveyed using EMI sensor simultaneously in horizontal and vertical orientations with a different depth response profile. The surveys were carried out in May, after harvesting a cabbage crop and before planting a tomato crop, and in September, after harvesting the tomato. The same field was investigated with a WorldView-2 satellite in April and in July, when cabbage and tomato were present, respectively. The NDVI vegetation index was calculated on the two dates.

The multivariate spatial structures of EMI data in two orientations, for each date, were investigated by means of a linear model of coregionalization (LMC) fitted to all direct and cross-variograms, by expressing each variogram as a linear combination of the same basic structures. Finally, each temporal subset of variables was interpolated on a 1 x 1 m-grid using cokriging.

A univariate geostatistical approach was applied to analyse NDVI data. Two direct variogram models were separately fitted for each date, and subsequently interpolated on the same grid using the kriging technique. In order to obtain spatially contiguous clusters, a clustering algorithm based on nonparametric density estimate, along with a smoothing parameter, was applied to the whole data set of the estimated variables including also the spatial coordinates.
The cokriged maps for EMI variables seem to reveal high degree of continuity along the profile because both the vertical and the horizontal EC_a maps look quite similar. Moreover, they seem consistent over time because the September and May maps look quite conservative. The wide area at the eastern part of the field, characterised by higher EC values, may be related to differences in soil texture.
The kriged maps of NDVI underline that the remote sensing imaging is mostly influenced by crop management, as the main spatial structures appear stretched out in the direction of the cultivation rows. As well as for EMI maps, the remote sensing images show a temporal consistency over time.
The clusters obtained by the combined approach identify homogeneous zones to be likely related to different soil properties and crop responses. The eastern area of the field, characterised by the highest values of EC, is also associated with the highest values of NDVI. This means that in this portion of the field there occur environmental conditions which are more favourable for plant growth, no matter the type of crop. However, only a direct soil sampling can disclose the causes of such variation.
The proposed algorithm has proved quite efficient into combining data coming from different sensors and has stressed the necessity to adopt a holistic approach in site-specific management.

FUSION OF HYPER-SPECTRAL AND THERMAL IMAGES FOR ESTIMATING NITROGEN AND WATER STATUS IN POTATO FIELDS FOR VARIABLE RATE APPLICATION

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Potato yield and quality are highly dependent on an adequate supply of water and nitrogen. The relatively shallow root system of the potato crop coupled with a high nitrogen (N) requirement and sensitivity to water stress on coarse textured soils increases the risk for nitrate leaching. Therefore, water and N management for potato is important both from production and environmental standpoints. Applying the right amount of N and water in the right place at the right physiological stage is a challenge for potato growers. Matching irrigation and fertilization management to the demand of the crop requires an adequate assessment of water and N status in agricultural landscapes, especially early in the season when management decisions can impact the yield. Opportunities exist to use airborne hyperspectral (HS) remote sensing for the detection of spatial variation in N status of the crop to allow more targeted N applications. Thermal remote sensing has the potential to identify spatial variations in crop water status. The overall objective of this study is to examine the ability of HS imagery in the in the visible and NIR spectrum (VIS-NIR) and thermal imagery to distinguish between water and N status in potato fields. To accomplish the overall objective we propose: 1. a new unmixing methodology to combine ground-based high-resolution images in the visible range with thermal imagery to evaluate water status of potato plants; 2. chemometric and segmentation methods for hyper-spectral imagery analysis for N level evaluation and mapping in potato fields; and 3. a new method to optimally fuse HS aerial images in the VIS-NIR with thermal imagery to evaluate and map water and N status in potato fields. In this framework we will show initial results of the following analysis types: 1. Partial least square (PLS) applied for spectral measurements to estimate N levels in potato plants; 2. Segmentation of aerial HS images, using a modification of the Beamlet method, to identify homogeneous zones of N levels in a potato field; 3. Evaluation of water status of potato plants based on thermal images.

REMOTE ESTIMATION OF CROP BIOPHYSICAL CHARACTERISTICS: FROM CLOSE RANGE TO SATELLITES

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Regional and global monitoring of the condition of agricultural vegetation is important. Several biophysical parameters are indicators of crop status including spatially distributed vegetation fraction, fraction of absoprbed photosynthetically active radiation, integrated crop canopy chlorophyll content, leaf area index and gross primary productivity. We report our progress in developing and implementing remote techniques for estimating the above biophysical characteristics at close range, as well as at aircraft and satellite altitudes. A suite of vegetation indices was developed for assessing crop physiological and phenological status, and for detection of the early stages of vegetative stress. The performance of the developed techniques is demonstrated by assessing the biophysical characteristics of both rainfed and irrigated maize and soybean at three AmeriFlux sites during 2001-2008. These results suggest new possibilities for accurate assessment of crop “health” at close range as well as when using Landsat Thematic Mapper imagery, and the 250-m/pixel data currently being acquired by MODIS and MERIS.

ESTIMATING CROP PARAMETERS AND LAI THROUGH INVERSION OF HYPERSPECTRAL CANOPY REFLECTANCE DATA

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Hyperspectral remote sensing offers new possibilities of non-destructive parameter estimation for soil and vegetation. The use of remote sensing techniques in agriculture in the past was limited due to poor data availability. The Julius Kühn Institut (JKI) is currently developing a ground-based online system, capable to obtain high-resolution reflection data in the field.
The Penta-Spek system consists of six spectrometers to record the spectral reflectance in 110 narrow bands (bandwidth 5 nm) in a wavelength range of 400-950 nm. One spectrometer records the incoming radiation and thereby continuously provides this as a reference to the other five spectrometers, so that spectral reflectance can be determined in the field directly. The spatial resolution of the system depends on the driving speed of the vehicle. Depending on the application, resolution in centimetre range (e.g. for small scale plots) or up to 5 m ground resolution can be achieved. The hyperspectral point measurements are finally extrapolated to a larger spatial extent by using geostatistical techniques.
The analytical potential of hyperspectral data ranges from determination of soil parameters to the application of radiative transfer models for the determination of vegetation parameters. Radiative transfer models such as ProSail allow the calculation of spectral signatures based on various vegetation input parameters (e.g. LAI, chlorophyll content). By inversion of these models, crop and vegetation parameters can be retrieved from the measured hyperspectral reflectance data.
The Penta-Spek system allows a cost effective collection of hyperspectral data in the field. Through the continuous measurement of the incoming light, illumination differences are compensated directly from the measurement.

TWENTY FIVE YEARS OF REMOTE SENSING IN PRECISION AGRICULTURE: KEY ADVANCES AND REMAINING KNOWLEDGE GAPS

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Precision agriculture dates back to the middle of the 1980's. Remote sensing applications in precision agriculture began with sensors for soil organic matter, and have quickly diversified to include satellite, aerial, and hand held sensors. Wavelengths of electromagnetic radiation initially focused on a few key visible or near infrared bands. Today, electromagnetic wavelengths in use range from the ultraviolet to microwave portions of the spectrum, enabling advanced applications such as LiDAR, fluorescence spectroscopy, thermal spectroscopy and time domain reflectometry, along with more traditional applications in the visible and near infrared portions of the spectrum. Spectral bandwidth has decreased dramatically, allowing improved analysis of specific compounds and molecular interactions, and enabling advances in hyperspectral remote sensing. As a consequence, a variety of spectral indices now exist for various precision agriculture applications, rather than a focus on only normalized difference vegetative indices. Spatial resolution of aerial and satellite remote sensing imagery has improved from 100's of m to sub-meter accuracy, allowing evaluation of soil and crop properties at fine spatial resolution at the expense of increased data storage and processing requirements. Temporal frequency of remote sensing imagery has also changed dramatically, with early emphasis on imagery collected once or twice a year. At present there is considerable interest in collecting remote sensing data at multiple times in order to conduct near real time soil, crop and pest management.

PRECISION AGRICULTURE IN DAIRY FARMING: DETECTION OF SICK COWS

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Recent availability of behavior sensors allows continuous monitoring of behaviour variables in order to detect health and welfare problems during transition time, which is the most sensitive period along lactation.
The objectives of this study were to analyze behavior variables of healthy cows during transition time in relation to age, environmental conditions and production performance to serve as a "base-line" for diversions that indicate welfare or health problems.
The trial was conducted from 2007 until 2010 in three commercial dairy farms of varying size (60 - 250 milking cows). Individual data from behavior sensors (lying time, lying bouts, maximal steps per hour) and production sensors (milk yield and body weight) were collected from 210 healthy multiparous cows during the first 28 days after calving. Data were analyzed for calving season, age of cows and then divided into two subgroups: one with positive correlation between milk yield and lying time and one with negative correlation.
Lying time increased significantly with age and is significantly higher in winter than in summer. During 4 to 5 days after calving, the cow spent less time lying down then later in lactation, which correlated with the maximal number of steps per hour. Maximal number of steps per hour was significantly lower in winter compared to summer for all cows. In winter, older cows had a significantly lower maximal number of steps per hour than second lactation cows. 60 % of cows that calved in summer had a negative and 40 % a positive correlation between milk yield and diurnal lying time. For cows that calved in winter, it was 38 % and 62 % respectively. Summer calving cows that had a positive correlation between milk production and lying time had significantly lower maximal number of steps per hour. For second lactations cows, the lying time is significantly higher for the positively correlated cows than for the negative ones. The maximal number of steps per hour is significantly higher in the positively correlated cows with more than two lactations than in the negatively correlated cows. For summer calving cows and for second lactation winter calving cows, lying time starts decreasing despite the fact that milk yield is still increasing when there is a negative correlation between milk production and lying time.
This study indicates that behaviour variables during transition time in the commercial dairy farm measured in this study are affected by calving season and lactation number. Positive and negative correlations between milk production and lying time are strongly affected by calving season, in opposite proportions between summer and winter.

PRECISION AGRICULTURE IN DAIRY FARMING: EXPERIMENTAL SETUP FOR A COMPUTER VISION BASED AUTOMATIC LAMENESS DETECTION SYSTEM

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Lameness is still a major concern in modern dairy farming. Under conditions of robotic milking, painful lameness impairs with visits to the milking station and reduces milking frequency. Additionally, the issue is part of the intensified welfare societal discussions. The prevalence of lameness ranges from 9% to 50%, depending on several farm conditions. This prevalence might even be an underestimation due to the low awareness, difficult recognition and the poor registration of lameness cases. The economic impact of lameness is significant for the farmer, because losses increase with severity and the type of lameness. These losses comprise the treatment costs, the indirect losses of decreased milk yield, reduced fertility, higher replacement rates and a lower selling price of the culled lame animal.

In research lameness is often visually scored by a trained person in order to rate the lameness incidence on the farm. There are several scoring methods available in literature. The most used method is the 5-point lameness scale developed by Sprecher *et al.* (1997). However, the hypothesis is that lameness scoring in practical situations is hardly done. When done, it is not frequently enough and uniformity in scoring methods will not be present. This was the main reason for several researchers to start the development of automatic scoring methods that mimics the farmer‘s observations. Using video images might be a logic next step. Some prior experiments were done to automate this process by video recording of cow gait and analysis of locomotion which revealed that the curvature of the arched back and the step-overlap of a walking cow could be used as good indicators for lameness severity. In this research we would like to elaborate on the practicability and robustness by also looking at different cows (genetics) held in different circumstances (climate, housing, feeding).

The objective of this project is to study an automatic detection system to quantify the severity of lameness for dairy cows, based on both analysis of video recordings of the cow‘s gait associated with behavior.

The poster describes the experimental setup in a commercial dairy farm. The average milk production on the farm was 12500 kg/year/cow. The cows were housed in a fully roofed free stall parlor without cubicles and dry manure floor. The cows were milked in an adjacent concrete-floor parlor. The cows were fed concentrates according to their milk production, and a TMR twice a day, supplied by a local cooperation.

Cow gait was recorded using two colour cameras, one with a resolution of 1032x778 pixels and the other with a resolution of 800x600 pixels, both in RGB color format and at a frame rate of

30 fps. The images were taken in a concrete-floor corridor when the cows left the milking area. A separation gate made the cows enter the corridor one by one. The camera with highest resolution was positioned in a side view position, and the smaller camera in a top view position. The animals were scored visually by using the 5-point scale of Sprecher *et al*. This scoring will be used as a golden standard for the validation of the automatic detection algorithm developed in this experiment. Visits to the milking station and feeding stations were recorded by the management software. This poster describes the need for this type of research and development, and will discuss the experimental setup of the experiments.

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WIRELESS SENSOR NETWORK APPLICATIONS IN AGRICULTURE

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Many sectors of society are experiencing a wireless revolution. Yet, this revolution appears to be conspicuously absent in agriculture despite technological advances which make it conceivable to build and deploy wireless sensor and control networks which would radically improve farm efficiencies. This is because current wireless technologies are too expensive, too unreliable, or too complicated for the farm. However, that's about to change because of the rapid pace of development of wireless communications. Based on our experience, we are convinced that during the coming decade, wireless sensor networks will offer the same type of quantum leap forward for farming that GPS provided during the past decade.

Field Crops

Theme Heads

Shai Meital & David Bonfil

CHANGE DETECTION USING UNMIXING IN AGRICULTURAL LANDS ACROSS THE MEDITERRANEAN CLIMATE REGION OF ISRAEL

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Change detection is the process of identifying differences in the surface conditions by observing it at different times. The basic premise in using remote sensing data for change detection is that changes in land cover must result in changes the surface reflectance which is represented over large regions by satellite images.

Change detection has a role in identifying variations in land use and land cover. These temporal and spatial variations are the consequence of economic, ecological, and social process. Better understanding of past processes may enable the improvement of planning strategies in general and agricultural practices in particular.

A variety of change detection techniques have been developed. This research uses the linear mixing model (LMM). The basic premise of mixture modeling is that within any image pixel the surface is dominated by a number of distinct materials that have relatively constant spectral properties. These distinct substances are called end-members.

In LMM a pixel's observed reflectance is modeled as a linear combination of these spectrally pure end-members reflectance. Each end-member contributes proportionally to the overall spectral response according to its relative abundance within the sensor's instantaneous field of view (pixel). To estimate the fractional cover of each end-member within a given pixel, the mixing equation has to be solved for all image bands simultaneously, using a least squares approach.

The advantages of this technique are that the end-member fractions have a biophysical meaning and that the results are considered stable, accurate and repeatable.

Most of the existing studies that use LMM for the purpose of change detection, concentrate mostly in afforested or urban regions.

Israel and other Mediterranean regions are characterized as transition zones, where patches of vegetation compositions vary dynamically in response to variations in the local habitat conditions. This land cover structure makes change detection more complicated.

The technique that is proposed in this research handles the heterogenic regions in the image by applying edge detection on the images from the different years and comparing them. Addition or diminution of an edge indicates of a change while an edge in the same location indicates for no change. Regions which were defined as homogenous at both years are then examined for detecting possible change by employing the LMM technique.

The new approach is implemented in an agricultural zone in Central Israel where there had been significant landuse changes as well as changes in crops.

UTILIZING DAILY SATELLITE IMAGERY FOR FARMING ORIENTED INFORMATION

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Precision farming requires updated information on local spatial scale, such as meteorology and plant growth on a field-by-field basis. Land surface temperature (T), as map by satellite imagery can be used for temperature, while the normalized difference vegetation index (NDVI) can be utilized to map plant vigor. However, daily satellite imagery are not usually utilizing for this information. The goal of this project is to provide land managers with field-base information for day-to-day decision-making.

We are using the Moderate Resolution Imaging Spectroradiometer (MODIS) red, near-Infrared and temperature products to represent the daily minimum, maximum and average T and the NDVI. The MODIS temperature is down-scale to 250-m, the same pixel size of the NDVI. The T is calibrated to several weather stations while other stations are used as independent dataset for evaluation. Crop biomass was collected to calculate present of dry matter and tensiometers were used to calculate potential soil holding water capacity.

The results show >95% correlations between the calibrated T and the independent weather station dataset. For field base management, we utilized this dataset to calculate growing-degree-days, which fit the growth of the crop at that field. Further, we found the T/NDVI index correlate much better to present crop dry-matter or the tensiometers datasets than the NDVI. We also revealed that mapping this index with morning temperature or nightly temperature has the results, allow minimize cloud disruption. The resulted T/NDVI index product can be used to: (1) design harvest logistic; (2) identify irrigation catastrophic in a specific plot.

MEAN SHIFT-BASED CLUSTERING OF REMOTELY SENSED DATA

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The *mean shift algorithm* (MSA) is a statistical approach to the clustering problem. The method is a variant of density estimation. We present in this paper the approach and its use for clustering of remotely sensed images. We also provide experimental results obtained from real data sets, which indicate that the MSA technique has a fairly good accuracy and high reliability. The adaptation of the procedure to a parallel environment is also discussed and demonstrated. The method was implemented for mapping 5 crop types from multi-temporal Landsat TM data: wheat, vetch, cotton, sunflower and orchards. Although the classification accuracy and reliability seem to be similar to those obtained by other unsupervised methods, MSA presents several important operational advantages.

PERFORMANCE ANALYSIS OF VENμS BANDS ASSESSMENT OF LAI BY RED-EDGE INFLECTION POINT

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The red-edge region of the energetic spectrum at the leaf level is the region connecting the chlorophyll absorption in the red wavelengths and the amplified reflectance caused by the leaf structure in the Near Infra-Red (NIR) region. In the canopy level, the inflection point of the red-edge slope is influenced by the plant's condition that also relates to chlorophyll content but the NIR is now mainly affected by the Leaf Area Index (LAI). Monitoring vegetation condition is important for agriculture, therefore many spectral indices have been developed. Combining high spectral and spatial resolutions can allow precision agriculture applications. An example is the Vegetation and Environmental New micro Spacecraft (VENμS) future satellite putting on use 11 different bands, four of them in the red-edge region and with spatial resolution of 5.3m. The aim of this study is to present the VENμS potential abilities for LAI assessment. The research was conducted in experimental plots of wheat and potato in the north-western Negev, Israel. Data were acquired during four seasons, two seasons for each crop. Spectral data were obtained by a field spectrometer and followed by LAI measurements obtained by a field ceptometer. The spectral data were resampled to the superspectral VENμS bands resolution. Red-Edge Inflection Point (REIP) and Normalized Difference Vegetation Index (NDVI) were calculated by specific as well as by VENμS resampled bands. The results show general (both wheat and potato together) advantage for the REIP over the NDVI when correlated to LAI, presenting highly significant R^2 values of 0.63 and 0.44, respectively. The REIP had also advantage over the NDVI, peaking with wheat predicting of LAI to R^2 values of 0.86 and 0.61 with root mean square error prediction of 0.66 and 1.13, respectively. There was no significant difference between narrow band indices or VENμS resampled indices in any of the cases. Based on these results, VENμS resampled superspectral data is concluded to be as applicable as hyperspectral data for predicting LAI of field crops.

HIGH SPATIAL RESOLUTION GROUND-LEVEL HYPERSPECTRAL IMAGING FOR WEED DETECTION

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Weeds are a severe pest in agriculture, causing extensive yield loss. Control of grass and broadleaf weeds is commonly performed by applying selective herbicides over the entire field. As presented in several studies, applying the herbicide only where needed has economical as well as environmental benefits. Combining remote sensing tools and techniques with the concept of precision agriculture has the potential to automatically locate and identify weeds in order to allow precise control. The objective of the current work is to detect annual grasses and broadleaf weeds among cereal as well as broadleaf crops. In order to do so ground level hyperspectral images were obtained by the Spectral Camera HS (Specim). The camera is a push broom scanner with 1600 pixel per line and 849 narrow bands in the range of 400-1000 nm. It was placed 135 cm above the higher parts of the canopy resulting in a pixel size of 0.4 to 0.6 mm. The images were radiometrically corrected and transformed to relative reflectance values by the flat field method based on white reference, pressed and smoothed barium sulfate ($BaSO_4$) powder placed in each of them. The data were analyzed in two ways: general discriminant analysis (GDA) and decision tree. Spectra from more than 20 images, all together more than 1500 pure pixels of wheat, potato, grass weeds, and broadleaf weeds were obtained. Each of the four groups has more than 300 pixels of which at least 150 of them are of shaded pixels and the rest, also more than 150 pixels, were naturally illuminated. The data were classified by GDA models for the Mahalanobis distances method. The results of the validation model for the four groups presented total value of 83.6% correct with the lowest value of 79.9% for wheat. Classifying wheat and grass weed and potato and broadleaf weeds resulted in total values of 83.7% and 92.9% correct, respectively. When coupling broadleaf weeds to potato in order to classify against wheat and coupling wheat and grass weeds to classify against potato the total values were of 91.8% and 98.9% correct, respectively. Therefore we concluded that spectral separation of grasses and broadleaf weeds among cereal as well as broadleaf crops is possible. A decision tree was build in order to provide spatial properties to the following groups: vegetation, soil, glint, shaded vegetation and shade. It was resulted in more than 95% accuracy for all groups. The vegetation output of the decision tree is to be the base for separation between crop and weeds. During the data analysis it came to our attention that vegetation indices (e.g., NDVI, GNDVI, and REIP) tend to obtain higher values in shaded vegetation pixels than in naturally illuminated ones, this is to be further explored. The data analyzing methods mentioned above will be applied again for the same images and pixels after resampled to the bands formation of the superspectral future satellites Vegetation and Environmental New Micro Spacecraft (VENμS) and Sentinel-2.

CHLOROPHYLL CONTENT MESUREMENT IN BELL PEPPER BY VIS-NIR SPECTROMETRY

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Export markets show increasing demands for high-quality and colorful assortment of bell peppers. Bell peppers are one of the main export produce of Israeli farmers. Several cultivars with large variety of colors are grown mainly in greenhouses or net-houses, in the southern part of the country. For high quality requirements mature peppers should be harvested, in some cases without the full change of color. Reducing of chlorophyll content in this case is one of the major maturity indices. The objective of the present study is to develop a fast and nondestructive method to measure chlorophyll content in bell pepper. The research is using VIS-NIR spectrometry. Three varieties were examined: red, green and yellow; *Silica, Evergreen* and *No.117* respectively. Peppers were marked in flowering stage and 20 samples from each variety were collected weekly, along growing period of seven weeks, until full growth. VIS-NIR spectra of intact pepper were obtained with USB2000 (Ocean Optics, Dunedin, FL, USA) mini spectrometer, bandwidth: 350-1000 nm, grating: 600 lines blazed at 750nm, 2048 wavelengths with bi directional fiber optic (BIF600-UV-VIS) and LS-1 Tungsten Halogen Light Source. Disk of the fruit flesh were cut out from area of VIS-NIR scanning and were analyzed by a destructive analytical protocol. The spectrometer's data were analyzed by chemometric procedures: partial least squares regression (PLSR) software was used for model development (PLS, Eigenvector Research, Wenatchee, WA, USA), run under MATLAB software (MathWorks, Natick, MA, USA). Comparisons were made between the PLS regression analysis of the raw reflectance spectra (R), and the pre-processed spectra such as the first derivative of R (D_1R), log(1/R), D_1(log(1/R)) and D_2(log(1/R)). Furthermore, several well known vegetation spectral indices, such as NDVI, were examined. Modified index was obtained using specific peaks of bell peppers spectra. High correlations were obtained with these indices up to r=0.82. Detailed results will be presented.

SPECTROSCOPY AND HYPERSPECTRAL IMAGERY FOR MONITORING OF SUMMER BARLEY

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Spatial heterogeneity of agricultural fields always results from ecological conditions and current management practice. Infield variability produces over- and/or undersupply of agricultural inputs, resulting in economical and ecological drawbacks. Modern agriculture requires basic information to apply site-specific soil and crop management. The technologies used to manage spatial and temporal variability are associated with all aspects of agricultural production. Remote sensing techniques play an important role in modern agriculture by providing important data of soil and agricultural crops and especially hyperspectral data allows a detailed quantitative assessment of soil properties and vegetation parameters. Principally, regionalization of agricultural properties by utilizing remote sensing is a valuable tool for the identification and handling of infield variability. In case of image data, the spatial coverage of the data can provide spatially distributed soil or vegetation data of the fields.

The potential of field spectroscopy will be shown by the quantitative assessment of vegetation parameters such as leaf area index, canopy chlorophyll, and canopy nitrogen or canopy water content for a study site in Germany. A data set has been acquired, comprising top of canopy reflectances (0.4 – 2.4 µm) and the corresponding canopy parameters of summer barley canopies over the full phenological crop cycle. Vegetation parameters were predicted by partial least squares regression (PLSR). The influence of spectra pre-treatment techniques including min-max normalization, first derivative and vector normalization on prediction accuracy is addressed. For further analysis spectra were resampled to the spectra resolution of the HyMap sensor. Leaf area index, canopy nitrogen and canopy water content were predicted from field reflectance measurements with very high accuracy ($r^2_{cv} > 0.9$) while prediction of canopy chlorophyll content was less accurate ($r^2_{cv} \sim 0.7$).

Further on, special emphasis will be given to hyperspectral image data analysis for spatial prediction of crop related information. The hyperspectral image data were acquired by a HyMap airborne imaging sensor on May 28th, 2005. The sensor recorded spectra in the wavelength range from 420 to 2480 nm in 126 spectral bands with a ground resolution at nadir of approximately 5 m. Image pre-processing was performed including across-track illumination correction and both atmospheric and geometric correction steps.

PLS regression models obtained from field spectra were applied to HyMap data to allow spatial prediction of summer barley canopy properties. Subsequently, to assess accuracy of the spatially distributed estimates, predictions obtained from the image data were validated with reference to the vegetation samples taken in the field. The predicted vegetation parameters reflect the spatial conditions of the investigated plot. The results indicate the potential of this method as a quick screening tool for the spatial assessment crop canopy parameters.

SPATIALLY ADAPTIVE HYPERSPECTRAL UNMIXING IN AGRICULTURAL AREAS

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While there are numerous algorithms for spectral unmixing, there are very few methods which utilize spectral information from the Pixel's neighborhood in order to improve the unmixing process. Spatial knowledge is important first, for identifying the end-members which are most relevant for solving each mixture, and secondly it may allow extraction of end-members which are present at the vicinity of each pixel, and thus adapting to the specific type of mixing which occur in different image regions. Implementing this approach requires an iterative process which starts with assessing the spectral distance (SAM) between the spectra of each pixel and an initial set of end-members' spectra. It is then possible to identify areas where these end-members are unlikely to explain their spectral reflectance. These areas may represent new type of mixtures: new image end-members. After adding the new sets of end-members the image is divided into areas of spectral gradient from a core area of a single dominant end-member, and areas of homogenously mixed pixels. Unmixing in these two typologies is conducted then using our new Iterative technique but using only the relevant end-members.

The new technique is employed in a rural area in northern Israel representing orchards, field crops and abandoned fields. Using the methodology we differentiate between areas dominated for example by olive trees, then their mixing with the soil background, and finally areas of homogenous mixtures such as those of soil covered by grasses. The methodology had been proved as efficient for mapping agricultural regions while being sensitive to the different mixing typologies at the vicinity of each pixel.

PRECISION NUTRIENT MANAGEMENT: CHALLENGES AND OPPORTUNITIES IN A FLAT WORLD

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Precision nutrient management is well documented concept that has been widely researched and practiced across the globe. There are trends reported by scientists, practitioners and agencies that indicate there has been an increase in nutrient use efficiency over the past 30 years. However, it is not clear if such increase could be attributed solely to precision nutrient management. Irrespectively, an increase in nutrient use efficiency is a welcome sign for agronomist and soil scientists engaged in precision nutrient management. While it appears that we are on the right track there are still numerous challenges ahead of us in achieving the various "R"s of precision nutrient management, which include the Right source, the Right time, the Right amount and the Right place. More challenges confront us if we were to expand our horizon across the globe in today's world. In today's environment we are increasingly living in a flat world where we are no longer insulated from external factors. In a flat world, an increase in fertilizer demand in Asia impacts the fertilizer prices in the USA or a crop disaster in Russia influences the global commodity prices, or food scarcity in Haiti or Indonesia become a cause of global concern. With increasing global population and limited or decreasing arable land available for crop production the question arises "will we be able to overcome the future challenges and seize them as opportunities?" Precision nutrient management coupled with water management and genetic improvements in crop traits will play a crucial role in meeting these challenges of our times.

ET COMPONENTS INVESTIGATED INDIVIDUALLY - TESTING THE TWO SOURCE MODEL IN AN ARID VINEYARD

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One of the less explored questions regarding evapotranspiration (ET) in crops is how to account for the individual contributions of surface evaporation (E) and crop transpiration (T). This is particularly relevant in row crops, where management practices in the interrow can significantly affect the total evapotranspiration flux.

This research aims to quantify individual ET components in a vineyard situated in an arid area. Firstly, by investigating two novel technologies developed to determine soil evaporation independently: a micro-Bowen-ratio system, and soil heat pulse probes. Secondly, by testing the ability of the Two Source Model (TSM) to accurately separate E and T by comparing model outputs to measured fluxes. The TSM is a well tested model that gives good estimates of ET, and is based on the surface energy balance; using meteorological data and remotely sensed temperature and leaf area data as inputs. The model computes ET by iterative calculations using two sources: canopy transpiration and soil evaporation, but the accuracy of the individual components E and T have not been validated. Field measurements include: 1) Meteorological measurements: solar radiation, air temperature and humidity, wind speed and direction, 2) Flux measurements: net-radiation (3 locations), soil heat flux (5 locations), ET and sensible heat flux (eddy covariance), E (micro Bowen ratio systems and heat pulse probes), 3) Temperature measurements: surface (infrared thermometers) of the canopy, the soil (interrow and below vine), and the entire vineyard (soil and canopy). Initial results show interesting dynamics in the energy fluxes along the cross-section between vine row and interrow.

COMBINED SPECTRAL INDICES FOR REMOTE SENSING OF LEAF CHLOROPHYLL CONTENT OF DRYLAND WHEAT

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Most ground-based optical sensors utilize spectral indices (SI) to estimate wheat (*Triticum aestivum* L.) chlorophyll a and b content (C_{ab}) critical for advising in-season nitrogen fertilizer needs. These indices are sensitive to C_{ab}, leaf area index (LAI), and soil background variation, but relative sensitivities to these three factors vary for a given index. Combining a SI primarily sensitive to C_{ab} with an index primarily sensitive to LAI has been shown to improve chlorophyll estimates. However, relatively little is known about the sensitivity of these combined indices to soil background effects. The objective of this study was to evaluate the sensitivity of combined spectral indices to variation in soil reflectance and how this may affect overall index performance for ground-based sensing of C_{ab} in wheat. Selected spectral indices were extracted from spectra simulated by the PROSPECT+SAIL radiative-transfer model for various LAI and a total of 121 dry soil surface reflectance spectra. These spectra were selected to represent the diversity of soils across the major wheat growing areas in the United States. Soil properties and reflectance varied widely among the diverse soil types indicated by the high index variation for LAI values < 1.5. The Normalized Difference Red Edge Index/Normalized Difference Vegetation Index (NDRE/NDVI) was least affected by soil background variation. Overall, soil background variation contributed considerably less to the observed index variability (<6%) than LAI (<97%). The combined indices NDRE/NDVI and the Modified Chlorophyll Absorption Ratio Index/Second Modified Triangular Vegetation Index (MCARI/MTVI2) accounted for most of the variance attributable to both soil background and LAI and showed high sensitivity to chlorophyll variation. This suggests that ground sensing of chlorophyll may be improved through the use of combined indices to accommodate extraneous variation due to soil reflectance and LAI. Further research is needed to evaluate the effect of soil moisture, surface roughness, residue, growth stage and shadow on the studied indices.

ECONOMICS OF REMOTE AND DIRECT SENSING IN AGRICULTURE

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Precision agriculture adoption data shows that farmers have been relatively slow to adopt variable rate applications of crop inputs such as fertilizers, pesticides, and seeds. While soil maps, remote sensing images, yield monitor maps, electrical conductivity, soil tests, and other measurements show what could be manageable variability within fields, most field crops worldwide remain managed on a field-by-field basis. This presentation will outline the economic factors limiting the use of agricultural sensing and the technical and management innovations needed to overcome these constraints. Accuracy, precision and timeliness are among the key factors determining the economic value of remote and proximate sensing data for making field level agricultural management decisions. A factor that has received less attention is the management time and effort needed to make use of the data. Management time and expertise is a scarce resource in all economic sectors, including agriculture. Consequently, on-the-go sensors linked to algorithms that make input decisions and implement them immediately will have an economic advantage over those technologies that require human input.

Higher returns to remote or direct sampling, and variable application for crop inputs are favored by inputs that have a relatively narrow optimum range with yield penalties for under or over-application, crops that have a high value, expensive inputs, an automated system that eliminates application delays and reduces human labor costs, and a low implementation cost for the spatial information and management decisions.

The economic tradeoff between manual sampling combined with laboratory tests vs. remote or proximal sensor data is the choice between relatively more accurate information at fewer points vs. somewhat less accurate information at many points. The important factors to consider for the grid or zone approach are the costs of sample collection, laboratory tests, and the crop production and input losses (i.e., too much or too little fertilizers, pesticides, seed) from the spatial inaccuracy and the time delay between sampling and implementation associated with this method. In contrast, the key considerations with the sensing approach are the cost of the technology and the crop losses inaccuracies and imprecision that may be associated with this method. For example, earlier studies showed that the economic gains from using a proximal soil pH sensor vs. a grid sampling approach to be positive but relatively modest. The increased density of samples provided over two thirds of the total benefit of automated proximal sampling, offsetting the higher measurement error.

CROP WATER STRESS MAPPING FOR SITE SPECIFIC IRRIGATION BY THERMAL IMAGERY AND ARTIFICIAL REFERENCE SURFACES

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Variable rate irrigation machines or solid set systems became technically feasible; however, crop water status map is necessary as a blueprint to match irrigation amounts to site-specific crop water demand. Thermal remote sensing can provide such maps in sufficient detail with timely delivery. In a set of aerial and ground scans at the Hula Valley, Israel, digital crop water stress maps were generated using geo-referenced high-resolution thermal imagery and artificial reference surfaces.

Canopy related pixels were separated from the soil by air temperature related upper and lower thresholds and canopy temperatures were calculated from the coldest 33% of the pixel histogram. Wetted artificial surfaces provided reference temperatures for crop water stress index (CWSI) normalization to ambient conditions. Cotton leaf water potentials related linearly to CWSI values with R2= 0.816, n=56. Aerial scan of cotton, process tomato, and peanut fields generated crop stress level maps corresponded well with ground based observations by the farm operators and irrigation history. Numeric quantification of stress levels was provided to support section wise decisions in spatially variable irrigation scheduling.

The method was tested in a semi-commercial campaign at the Yezrael Valley, where six weekly over flights monitored the water stress status of four cotton fields. According to the results, the system's feasibility for practical agriculture was demonstrated.

SPATIAL-SPECTRAL ANALYSIS FOR DETECTION OF SALINITY EFFECTS IN CAULIFLOWER, EGGPLANT AND KOHLRABI

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Salinity inhibits plants growth and reduces their yield. Salinity stress is a common phenomenon in arid and semiarid zones occurring naturally or due to anthropogenic influences such as irrigation using reclaimed water. In order to treat salinity stress and respond to water quality variability, it is essential to track salinity stress symptoms, and provide relevant information such as location and intensity of its negative effects. Imaging spectroscopy or hyper spectral remote sensing has the potential to provide site-specific information about crop status, due to its fine spectral and spatial resolution. Site-specific information has a major role in precision agriculture (PA). Imaging spectroscopy for PA purposes develops indices that are correlated to the cause of growth inhibition or to its symptoms. Spectral investigations of crop salinity effects and their assessment at fine spatial resolution (leaf scale) are relatively scarce. Most of the existing studies relate to salinity as spatially homogenous phenomena, looking at average reflectance values, while it is highly related to plant and leaf structure. This study was aimed at this gap with potential contribution for early warning of such effects as a facilitator of efficient improvement treatments necessary to prevent damage in crops' yield.

We hypothesized that salinity effects may form combined spectral-spatial patterns of reflectance, which are distinctive from those of healthy leaves. This hypothesis was tested by applying spectral and spatial techniques. The spectral techniques comprised selection of an appropriate Vegetation Indices (VIs) and the spatial techniques included separation of the image to segments.

Earlier spectral investigation, which included comparison of known VIs with a new index, concluded that the green and indigo spectral ranges can be used as the basis for the spatial analysis. The objective of the present work was to investigate the spatial characteristic of the chosen VI, Green Indigo Ratio (GIR) index, in order to delineate plants affected by salinity. Specifically, we propose a methodology for identifying spatial-spectral indicative pixels within a hyperspectral image, which express more clearly the investigated phenomena.

Hyperspectral images of the three crops were acquired during winter and summer, using a hyperspectral camera. All plant species were grown inside a greenhouse under similar and controlled environmental conditions, and supplied with the same nutrient solution (NPK 7-3-7). The plants were then divided into five treatments, in which sodium chloride (NaCl) was added to the nutrient solution in the following concentrations: 0 (control treatment), 30, 70, 110, and 150 mmol.

The spatial spectral analysis included techniques for image segmentation, local spatial statistics which measure autocorrelation around each pixel within an image, and image classification. The analysis included several stages. Delineation of the image portion containing only

vegetation was performed with VIs such as enhanced vegetation index. Later on, the vegetation area was divided into smaller segments (scale of leaves), applying the Getis Ord index (Gi) and the spectral angle mapper (SAM). These techniques transformed reflectance values into new values that were the base for segmentation. SAM was applied on reflectance values to detect segments based on spectral homogeneity. For this task, the spectral angle between neighboring pixels was calculated, instead of the traditional angle between the pixel and a reference spectrum. The Gi was applied on the reflectance value for detecting segments with different illumination levels, and on the GIR data, to detect segments of local minimum and maximum. Applying Gi on GIR (GGIR) provided an additional means to characterize salinity effects. It enhanced the differences between pixels from plants exposed to various salinity levels which included mainly low negative values, and control plants, which included mainly high positive values. The ratio between positive and negative GGIR values within an area of interest (PNR) provided additional means to detect salinity effects.

The performance of GGIR index and its PNR in detecting salinity effects were assessed using unsupervised k-means classification. The classification process was applied on a number of processed images: similar illumination level, local spectral homogenous and local minimum and maximum. GGIR and PNR, resulted in higher total accuracy and more significant separation between treatments than using other VIs.

FARMSAT - AN ADVANCED OPERATIONAL SYSTEM FOR PRECISION AG IN ISRAEL; FACTS AND UPCOMING IMPROVEMENTS

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Since 2008/9 the South Yehuda and Negev Growers own one of the most advanced Precision ag tool - *FarmSat* Israel. This is a web based system derived from operational applications already available and running in the US, Canada, Brazil and UK leading to a global synthetic solution of all the functions developed for these countries. The system is directly usable by the farmers for crop planning related to revenue forecasts, and for in season management: record keeping, management zones, scouting (real time detection of anomalies) and spraying operations (NPK, growth regulators and defoliants).

The real time monitoring is based on 10m satellite imagery calibrated with “in field” LAI and N measurements. At the moment the system can handle annual crops such as cereals, chickpea, cotton, maize and sunflower, and will be applicable for potatoes, orchards and vineyards in the near future, thanks to more accurate satellite imagery, thinner wavelengths and adapted models to the Israel varieties.

FarmSat Israel is based on the following concepts: “do the right thing at the right location and at the right moment” and “spray the right dose of input at the right location” for a better management of crops and reduction of production costs, in full respect of the environment.

Orchards

Theme Heads

Eran Raveh & Amos Naor

DIURNAL DYNAMICS OF CROP WATER STRESS INDEX OF OLIVE TREES - WHAT DOES IT REALLY TELL US?

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The Crop Water Stress Index (CWSI) is a water status indicator based on the canopy temperature. Its computation is based on the energy balance at the surface, with several parameterizations required. Diurnal dynamics of the CWSI of 15 2-year old olive trees (var. Barnea) planted in weighing lysimeters were studied. Prior to the experiment, the trees were irrigated daily, with quantities always exceeding the previous day's transpiration rates. Throughout the experimental period (August 28 through September 2, 2009), irrigation was withheld for 5 of the 15 trees, and by September 2 they were severely stressed. Daily irrigation continued for the rest of the trees. CWSI values were compared to actual evapotranspiration fluxes from the individual trees, with the CWSI well detecting the differences between the stressed and well watered trees. The diurnal pattern of the CWSI computed from the energy balance differed significantly from an empirical CWSI, indicating that some modification to the parameterizations implicit in the computations is required in order to be suitable for olive trees.

WHOLE-TREE WATER BALANCE AND INDICATORS FOR SHORT-TERM DROUGHT STRESS IN NON-BEARING 'BARNEA' OLIVES

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Drainage-weighing lysimeters allowed monitoring of water balance components of non bearing olive (*Olea europaea* cv Barnea) trees over a three month period including short term events of controlled but severe water stress. The objective of the study was to evaluate a variety of soil and plant based water status and drought stress monitoring methods on the basis of tree-scale evapotranspiration (ET). As the trees entered into and recovered from water stress, meteorological data, actual ET (ETa), soil water content and changes in leaf turgor pressure were continuously monitored. Additionally, midday measurements of stem water potential, stomatal conductance, canopy temperature, and quantum yield of PSII photochemistry were conducted. Diurnal (dawn to dusk) measurements of all the above were made hourly on days of maximum stress. Shoot elongation rate was measured for periods of stress and recovery. Quantum yield of PSII photochemistry, stomatal conductance, and stem water potential all successfully indicated reductions in whole-tree water consumption beginning at moderate stress levels. These measured parameters fully recovered to the levels of non-stressed trees soon after water application was renewed. Shoot elongation was reduced 25-30% for the 10 day period during and following drought and recovered thereafter to levels of non-stressed trees. Whole tree ETa was reduced by as much as 20% even following full recovery of the leaf level parameters, suggesting reduced canopy size and growth due to the stress period. Non-destructive, continuous (turgor pressure) and remotely sensed (canopy temperature) methods showed promising potential for monitoring effects of water stress, in spite of technological and data interpretation challenges requiring further attention.

COMPARING DENDROMETERS, SAP FLOW AND SOIL WATER SENSORS IN A 3 YEAR PERSIMMON IRRIGATION TRIAL

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Management of irrigation automatically depends on our ability to sense crop water status with automatic equipment that can transfer information for use in irrigation decisions. Several types of sensors have been shown to respond to irrigation treatments and have been commercialized in the past decades. It is important to include the different sensors in irrigation trials in order to develop the expertise needed to operate them and to investigate their efficiency in supplying reliable and accurate information on crop status. In this study a three year irrigation trial in Persimmon trees (Diospyros kaki L) with four irrigation treatments (50 to 170% of recommended irrigation) was used as a platform to study sensor response to irrigation. A standard meteorological station, providing data for calculating reference evapotranspiration, was installed in the orchard and appropriate numbers of sap flow, stem contraction and soil water sensors were installed and wired to a central data collection system. Manual measurements of leaf and stem water potential (SWP), photosynthesis, leaf conductance and fruit growth were made regularly. Other physiological and growth data, including yield, were measured. All sensors responded to irrigation levels and functions describing the response of yield to these were developed.

Soil sensor results showed a correlation between irrigation treatments to measured Soil Water Tension (SWT) and fruit yield. Differences were significant in parts of the season and only between extreme treatments. A strong relationship was found between maximum daily stem shrinkage (MDS) and SWP to soil water tension (SWT), where a decrease in SWT values was followed by a decrease of SWP and an increase of MDS.

The signal strength of MDS was higher in most parts of the season than all other indexes. The second strongest signal strength was SWT followed by sap flow (SF), fruit size and SWP. When including variability between sensors in the calculations, results were found to be the opposite. Signal/noise ratio was the highest for SWP throughout the season, i.e. 2.5 times larger than MDS and twice as large as SWT. This result points to the superiority of SWP compared to other indexes in terms of stability and the number of required repetitions needed in order to give reliable results. Testing the number (n) of measurements needed to find significant differences between the treatments showed that fruit size required the highest n (116 fruits per treatment) and the lowest n was needed for SWP (4.1 leaves/treatment). 18 trees were required for dendrometers, 11 for tensiometers and 7 for sap flow sensors.

EDDY COVARIANCE MEASURMENTS OF WATER VAPOR, CO_2 AND HEAT FLUXES IN A BANANA SCREENHOUSE

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The area of agricultural cultivation of vegetable crops and orchards in screenhouses and under screens is constantly increasing in Israel and other countries. The porous screens provide protection from unfavorable climatic conditions reduce insect invasion, and allow savings of irrigation water. Previous research demonstrated the feasibility of using the eddy covariance (EC) technique for surface flux measurements in the screenhouse environment. The aim of the present study was to optimize the use of the EC technique inside screenhouses by investigating the effect of the EC system installation height on the measured fluxes.

Measurements were conducted in a screenhouse in northern Israel which covered a banana plantation. Screenhouse dimensions were 250 m x 250 m and 6 m high. Energy and CO_2 flux measurements were made in the middle of the screenhouse using two eddy covariance systems each consisting of a three-axis ultra-sonic anemometer and an open path infra-red gas analyzer, positioned (at different time periods) 3.04, 4.02 and 5.06 m above the ground. During the measurement period, which lasted 25 days, plant height increased from 2.44 to 3.45 m.

Energy balance closure analysis of half hourly covariances for all three heights resulted with an average slope of 0.9 and an intercept of ± 15 W m^{-2} with $R^2 > 0.85$, supporting the validity of measured energy fluxes. Daily evapotranspiration increased from about 1.87 mm d^{-1} up to about 3.91 mm d^{-1} during the measurement period. The increase in net CO_2 consumption was 3-fold during the same period, from about 7.6 g m^{-2} d^{-1} to about 24.8 g m^{-2} d^{-1}. Consequently, the water use efficiency of the plantation, defined as the ratio between net vertical fluxes of CO_2 and water vapor, increased from 0.004 to 0.008 (gr CO_2/gr H_2O).

DETECTING IRRIGATION NEEDS TO IMPROVE WATER MANAGEMENT IN COMMERCIAL ORCHARDS

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Farm irrigation management is among the most complex of all agricultural practices. Such complexity, and the ever-increasing pressures on irrigation to reduce water use from other sectors of society have led to the development of an extensive array of technologies aimed at optimizing irrigation water use. Sixty years ago, soil water sensors were the first instruments introduced for orchard irrigation scheduling and they were adopted commercially in some areas. The use of plant water sensors for irrigation management lagged behind that of soil water sensors by about two decades. The pressure chamber was the first portable instrument that was rugged enough to be used under field conditions, and it was soon followed by the portable infrared thermometer. Many other plant sensors were used unsuccessfully, and some even resuscitated as their technical limitations were removed. The most notable example is that of trunk dendrometers, which were used since the fifties, achieved the same degree of precision they have today in the seventies, and they are being used again in the last 15 years, mostly for research purposes. Although the lack of adoption of all these sensors has many different causes, all of these sensors have a major drawback: they only provide point observations for the assessment of whole field behaviour. In the field, both spatial and temporal variability are the norm, because the spatial heterogeneity of soil water properties, combined with the variations in irrigation water applications, and with the variability in rooting depth and density, all generate wide variations in the level of water available to individual plants. To cope with such variability, the challenge becomes, therefore, to scale up the detection of field water status from point observations to whole fields. Recently, it has become feasible to detect the water status of whole fields with such a degree of accuracy that permits the assessment of the water status of individual trees *(Berni et al., IEEE Trans. Geosci.& Rem. Sen., 47,722-738, 2009).* Once this information becomes available, important issues that remain include how to use it effectively to schedule irrigation, what is the monitoring frequency, and what are the benefits and costs of using this novel approach as compared to the use of modern point sensor technologies. The presentation will delineate the potential of using high spatial resolution remote sensing for irrigation management of orchard crops, the options that offer for precision irrigation, and more importantly, the benefits that may be achieved by the more accurate irrigation management at the scale of commercial farms.

THE INTERACTION BETWEEN THE NUMBER OF FRUIT PER TREE AND WATER RELATIONS IN APPLE – IMPLICATIONS ON IRRIGATION SCHEDULING

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An old study demonstrated that crop yield of commercial size apples increases with increasing irrigation rate and with increasing the number of fruit per tree. Low irrigation rate was sufficient to maximize yield of fruit >70 mm at low crop level where further increase in crop level required higher irrigation rates. It may suggest that the tree can support the growth of low number of fruit even at water stress conditions which reduces assimilation rate – it is supported by the unique relationships that were established recently between apple fruit size and starch content in the branches regardless whether the assimilation rate (source strength) was manipulated by irrigation or the demand for assimilates (sink strength) was manipulated by fruit thinning.

Stem water potential is highly correlated with assimilation rate and fruit size and growers in Israel are using it to schedule irrigation in apple and other fruit trees. The current study shows that the relationships between stomatal conductance and stem water potential were altered by crop level in a way that higher stomatal conductance was apparent in high crop level trees at a similar stem water potential. It was hypothesized that the threshold of stem water potential for irrigation scheduling should be adjusted to the actual crop level that affects both the assimilation rate and the demand for assimilates. A field study was performed to confirm this hypothesis and the response of fruit weight to midday stem water potential was established for various crop levels. The results show that commercial fruit size is reached at higher water potentials with increasing crop level.

STEM EC PROBE: AN INNOVATIVE IRRIGATION CONTROLLER WHICH ACTIVATES VALVES IN AGRONOMIC CROPS BASED ON DIRECT EVALUATION OF THE PLANTS WATER STATUS

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During the last 50 years, the world is drifting continuously into a water crisis. Drought areas have been doubled, irrigated areas have been doubled, and water withdrawals from aquifers have tripled. The water crisis has affected all continents. Based on mathematical models, drought periods are predicted to double in the next century. Irrigation water availability will continue to decrease. Growers will be forced to increase their water use efficiency, by using precise irrigation. Currently available water stress sensors can be divided into soil sensors and plant sensors. The former are heavily dependent on soil heterogeneity (e.g., 40 soil-probes are needed in order to measure soil water status of one tree**)**. The accurate soil sensors (TDR and Neutron probe) are complicated and expensive, while the inexpensive sensors (as Tensiometers and Gypsum block) are inaccurate and their interpretation is questionable. Additionally, their measurements do not necessarily reflect tree water status. Plant water sensors, which give a direct measurement of plant water stress, including the pressure chambers (the most accurate technique that cannot be automated), as well as dendrometers and LVDTs (less expensive sensors) are sensitive to air temperature and cannot distinguish between swell-shrink trends caused by daily plant-water relations and continuous stem growth. Our new stem electrical conductivity (EC) probe is based on direct frequent and accurate measurements of stem electrical conductivity which is directly and closely correlated to the most accurate technique, namely, the pressure chamber. Its measurements are also in a good correlation with the accurate stem water content values obtained by the TDR technology (accuracy of 1‰). Its operation is based on a simple, common and an inexpensive technology (a small fraction of the operating costs of the TDR technology). Interpretation of stem EC measurement results, are independent of stem identity or properties and there is no need for calibrations. It gives a direct, physiological indication (therefore reliable) of the tree's real water need. Measurements are automatic (at pre-chosen intervals; e.g. 5 minutes), and the results, insensitive to variations in salinity and temperature, are analyzed by an algorithm. Currently, it has a proven saving of 35% in water and fertilization and it is further tested in three commercial orchards.

THE USE OF THE "ENVELOPE CURVE" MODEL FOR DETERMINING THE OPTIMAL LEAF MINERAL CONCENTRATION IN CITRUS ORCHARDS

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It is well known that orchard productivity is strongly dependant on its fertilization status. For many years, scientists have tried to correlate between tree yields and their leaf mineral concentration. Usually the correlation is based on long term experiments, since fruit yield is also affected by many others factors such as tree age, environmental conditions and the existence of biotic stress. Characterizing this correlation in alternate bearing trees is even more complicated, as fruit yield varies dramatically from one year to another. Due to the above complications, there are less and less publications dealing with yield and optimal leaf mineral concentration for trees. Recently, due to the development of remote sensing technology, scientists are trying to move into the next step of research, using multi-spectral imaging for monitoring leaf mineral concentration in trees. Yet, we cannot move into the remote sensing technology before we know the relation between fruit yield and leaf mineral concentration. For citrus, most of our data regarding optimal leaf mineral concentration is based on research from the late seventies, when scientists used agro techniques and varieties that are not relevant for today. Recently we have shown that optimal leaf mineral concentration can also be found by using the "envelope curve" of the relation between yield and leaf mineral concentration values. By using this technique we can overcome variation occurance due to the environmental and biotic factors that affecting yield. Using the "envelope curve" and the data from the national wastewater survey (a 7 year study) we reevaluated and characterized the optimal leaf mineral concentration for citrus in Israel. Unlike past recommendations, where optimal values were based on Florida recommendations, this time the data is relevant to the varieties and agro techniques used today by Israeli growers. The rationale behind the "envelope curve" as well as the new results will be discussed.

SAP FLOW MEASUREMENTS IN DATE PALM TREES – A MODIFIED APPROACH FOR WATER STRESS SENSING

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In a world of reduced water reservoirs and a rising demand for food, the role of precision agriculture becomes crucial. Hence, the practice and development of water stress indicators and sensors is at rapid progress. The heat dissipation method, originally established by Granier (1985), is here then induced and modified to enable sap flow measurements in date palm trees. Grown in arid climates, yet requiring large water quantities for optimal yields, the date palm trees are being vastly irrigated. In the southern Arava desert of Israel, palm plantations are irrigated as much as 2500 mm a year. Thus, in the new reality of extending cultivated areas and water quantity limitations, the need to optimize irrigation practices is crucial.

Plants water requirements change both seasonally and diurnally; thus, in order to optimize irrigation quantities it is essential to constantly monitor water use efficiency. As matured date palm trees' canopies are extremely high, gas exchange measurements for evaluating transpiration are hard to conduct. Furthermore, as the roots zone area is large, extending both vertically and horizontally, monitoring water consumption through soil water measurements is mostly inadequate. Therefore, it is critical to assess water utilization in a reachable and representative tree's component, such as the trunk.

The evaluation of the water passing through the tree's trunk, the sap flow, was conducted by a heat dissipation sensor. Having a constant resistance rather then a constant current, a modified 'Granier sensor' was formed. Sensors were inserted to four different depth of the stem, where the sap flow rate was constantly measured. When comparing between the different sensors, results exhibited a reduction in the sap flow rate in correlation with distance from the stem's center. Performing a set of hydraulic conductivity evaluations, to core samples taken from similar depths, reinforced those conclusions. Daily transpiration, as detected by the sap flow sensors, showed no transpiration through the night. In the first morning hours, from 6 to 9 AM, there was a high increase in transpiration rates; where after a more moderate climb was detected, reaching maximum transpiration values at about 12 AM. Later, there was a moderate reduction in transpiration rate until 8 PM, when water loss ceased. Those results came with agreements to gas exchange measurements and potential evapotranspiration as calculated from the Penman-Montieth equation. Thus, emphasizing the accuracy of the sensor's results.

AERIAL AND GROUND BASED THERMAL IMAGING FOR AUTOMATIC DETECTION OF IRRIGATION MALFUNCTIONS

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The losses to crops or plants caused by malfunctions of irrigation system in agriculture have a negative impact on agricultural system as a whole, being one of the reasons for its low economic profitability. Malfunctions are usually associated with improper maintenance or operation of irrigation system and appear as blockage or/and breaches in irrigation lines have both direct (i.e. water loss) and indirect (i.e. dryness) effects on within-field yield variability. Therefore, frequent monitoring of on-site irrigation system is an important task that farmers undertake. Though important, this task is labour intensive and generally uneasy to be implemented on regular basis. For that reason, the employment of a technology that improves the efficiency of large-scale monitoring of irrigation malfunctions could benefit to economic profitability of agricultural systems. Providing that surface temperature has long been recognized as an indicator of field and plant water status, here we present a preliminary results of our attempt to build an automatic approach for detection of blockages and breaches in an irrigation line of an irrigation system. The approach based on the assumption that any malfunction in irrigation system will either increase or decrease land surface temperature above or below its surroundings. According to this assumption, we will investigate the use of aerial and ground-based thermal infrared imagery to detect irrigation malfunction in grapevines, olives, palms, nectarine and apples. Preliminary results will be presented for grapevines only. Oblique ground-based and aerial thermal images were obtained above the irrigated grapevine located at the desert transition zone in the southern Israel. Five types of different irrigation amounts have been applied on six training plots of Thompson kind grapevine to simulate different types of malfunctions: (a) four days without irrigation; (b) six days without irrigation; (c) ten days without irrigation, (d) an excess irrigation and (e) commercially irrigated control plot. The above-mentioned treatments have been detected and separated (1) relatively by studying the anomalies in frequency of land surface temperature distribution across the field and (2) absolutely by mapping crop water status from digital infrared images of the canopy. Field measurements of leaf water potential and stomatal conductance have been performed simultaneously with image acquisition and were used for ground truthing. Finally, the effect of viewing angle and spatial resolution on separability between different irrigation treatments has been studied by comparing aerial and oblique ground-based thermal imagery.

SENSING AND INTELLIGENT AUTOMATION FOR ORCHARD MANAGEMENT

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It is estimated that at least 15% of the cost for operating a commercial orchard is spent on chemicals and fertilizers. In arid and semi arid regions water availability is also a major concern. Significant reduction of these costs is possible via better targeted application of inputs, including water. Furthermore, at least 45% of the total operating cost is spent on human labor - pruning, thinning and harvesting – whereas in many developed countries worker availability is also a big problem. Increasing labor efficiency through mechanization is a challenge for orchard cultivation and harvesting. This presentation discusses the state of the art and the future trends in sensing and automation technologies for orchard management. Furthermore, the concept of synergistic mechanization is discussed as an intermediate option between the extremes of manual and robotic labor.

Soil & Water Conservation

Theme Heads

Alex Furman & Naftaly Goldshleger

QUANTITATIVE ASSESSMENT OF LAND SURFACE PROCESSES UTILIZING THE ADVECTION-ARIDITY MODEL

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Spatial evaluation of land surface processes (i.e. desertification, degradation, soil conservation), in arid & semi-arid areas, is important in the process of understanding the water relations within agricultural and natural environments at all scales. The standard approach includes meteorological data and ground measurements that are, in many cases, sparse and consume significant effort.

We studies the ability to use remotely sensed (RS) imageries to evaluate the surface energy balance toward development of new reliable methodology to asses multi-scale surface condition based on physical approach of the Advection-Aridity model (Brutsaert & Stricker, 1979). Development of quantitative approach, based on RS surface fluxes (e.g. net radiation, evapotranspiration, surface temperature), is vital for multi-scale processes. The lag time between meteorological data collection and satellite overpass date is often the main problem in developing methods for extraction of knowledge about land surface processes. Therefore, predictive model that uses RS can help to overcome the gaps between ground data and satellite overpass timing.

The offered hybrid model combines vegetation density that is estimated from RS based vegetation indices (VI) and actual evapotranspiration (ETa), utilizing meteorological and RS data. The behavior of the model on a small field scale was demonstrated over an area irrigated by center pivot system and for the larger scale over the Hula valley region during winter and spring time. For winter time bare soil albedo varied between 0.16-0.24. High values were measured on Rendzina soil and low values on Peat. During spring, albedo varied between 0.20-0.38 for Peat and Rendzina, respectively. Surface temperature varied between 12.6c, for Alluvium and Rendzina soils, and 16.3c for peat soil during winter. The calculated Eta was 2.1 & 5.4 mm day^{-1} for winter and spring respectively. The net radiation throughout the winter ranged from 150 W m^{-2} for vegetated surfaces and up to 300 W m^{-2} for wet bare soils.

MONITORING ACTUAL EVAPOTRANSPIRATION WITH INFRA- RED RADIOMETERS AS INPUT IN SOIL WATER TRANSPORT MODEL FOR OPTIMAL IRRIGATION

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In order to combat the current worldwide water deficiency, efficient use of water is of the highest priority. The objectives of this study were: a) combine infrared radiometric systems (including meteorological sensors) to conventional Motorola-Aqua computer and remotely collect the output from a potato field; b) Develop a numeric mathematical model that is capable of - I) calculating actual evapotranspiration from the data collected in objective "a"; II) using the data from "I" as input for soil water flow model to obtain soil water content; c) To use the results as input for irrigation decision support system.

The Penman-Monteith equation has been solved for aerodynamic and canopy resistances and then used to calculate the plant water requirement. Further, the actual evapotranspiration was used as boundary conditions for instantaneous calculations of soil water content based on the hydraulic properties of the soil in Kibbutz Magen at the Western Negev. Results were compared to a target function that was based on known best potato growing conditions. The comparison between the target function and the measured remote sensing data were used to consider further irrigation steps. Currently, all components that are required to improve the potato irrigation are controlled remotely by Motorola-Aqua software. Including: data, models, hardware and software.

SPATIAL VARIABILITY OF CO_2 EMISSIONS IN A DRAINED FARMED PEATLAND OF THE VENICE WATERSHED, ITALY

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Systematic drainage of farmed organic soils is responsible for the occurrence of land subsidence, caused by loss of organic mass in form of CO_2 efflux to the atmosphere. This results in an increased risk of surface flooding, accompanied by higher drainage and pumping costs. A field experimental study has been performed in a drained cropped peatland located in the Zennare Basin (south of the Venice Lagoon, Italy), to measure land subsidence due to peat oxidation and to address the primary relationships between the hydrological regime, the soil mass loss, and the settlement rate. The latter, of the order of 1 – 2 cm/year, has been proved to be related to soil CO_2 efflux due to organic matter oxidation. Quantifying this process is thus extremely important for the management and protection of these areas. A series of CO_2 emission surveys has been performed between the years 2003 and 2005 by means of the non-steady-state chamber method, to measure the efflux spatial variability and detect its relationship with the main hydrological parameters controlling the oxidation reaction, i.e., soil temperature, soil moisture, and organic matter content. The measurements, carried out in two sites located 1.5 km apart, highlight a significant spatial and temporal variability of the CO_2 emissions. While the time-dependent behavior can be explained by the seasonal fluctuations of soil temperature, spatial variability shows a weak correlation with the variation of environmental variables. Statistical data analyses show that CO_2 efflux can be considered log-normally distributed and that the process is stationary within each site but not in the whole basin, though the properties of the outcropping peat layer and the soil surface seem apparently uniform. A geostatistical analysis reveals two different spatial correlation structures, with scales of spatial dependence of ~30 m and ~180 m. Finally, the collected data show that invasive agricultural practices such as deep plowing, tilling, and harrowing, largely used in the Zennare Basin, induce significant disturbances that are not easily recognizable during the flux surveys and that casually affect the temporal and spatial variability of the oxidation process.

STATIC AND DYNAMIC ASPECTS OF NON-INVASIVE MONITORING OF SOIL CHARACTERISTICS AND CONDITIONS

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Serious threats to soil conservation comprise soil erosion, decline in organic matter, local and diffuse contamination, sealing, compaction, decline in biodiversity, salinization, floods and landslides. One major prerequisite for the specific protection and restoration of soils is the availability of high-resolution soil property maps. Conventional, sample based soil property mapping is very time-consuming, cost-intensive, and the data collected are available only for discrete points in a landscape. Various soil parameters can be mapped using rapid, nearly non-destructive geophysical methods (Electromagnetic Induction - EMI; Ground Penetrating Radar - GPR; magnetic; seismics; gamma ray spectrometry). The key step to make a profitable use of geophysics to produce soil maps is that data be analysed quantitatively to offer meaningful information for the specific discipline object of investigation. A similar attempt to translate geophysical data into quantitative estimates of practical properties is currently made for many other applications, including environmental studies, hydrology and geotechniques. This approach leads to overcoming the classical view of geophysics as a pure imaging technique, and requires in-depth understanding of the information contained in each specific physical measurement. Irrespective of the specific application, the geophysical response of the near surface is essentially controlled by a combination of geological ("static") and ambient ("dynamic") factors. The latter include moisture content and temperature variations. In the case of soil mapping, the effect of ambient conditions is even more pronounced than for deeper applications, so time-lapse monitoring is essential to derive soil static information (esp. texture). The separation of static and dynamic factors is the key step towards a quantitative use of near surface geophysics, as individual disciplines and applications may be interested selectively in one or more of the static or dynamic aspects, or combinations. Physical-mathematical modelling is often a fundamental tool that helps to discriminate between static and dynamic aspects, extracting the factors of specific interest for the application at hand. A link between measured geophysical quantities and the corresponding quantities of practical interest can only be established in the form of quantitative constitutive relationships. As many applications can benefit from the joint application of multivariate geophysical measurements (e.g. ERT and GPR) it would be highly advantageous to develop constitutive laws that in turn depend on few parameters that can be independently measured and that have a common, albeit different, impact on several geophysical data. In this contribution we illustrate the research conducted within the EU 7th Framework Programme collaborative project *iSOIL*, that addresses the issues illustrated in the topic ENV.2007.3.1.2.1. "Development and improvement of technologies for data collection in (digital) soil mapping".

NUMERICAL INVESTIGATION OF IRRIGATION SCHEDULING BASED ON SOIL WATER STATUS

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Improving the sustainability of irrigation systems requires the optimization of operational parameters such as irrigation threshold and irrigation amount. Numerical modeling is a fast and accurate means to optimize such operational parameters. However, little work has been done to investigate the relationship between irrigation scheduling with irrigation threshold and the irrigation amount. In this paper, we compare the results of HYDRUS 2D/3D simulations with experimental data from triggered drip irrigation, and optimize operational parameters.

Two field experiments were conducted, one on loamy sand soil and one on sandy loam soil, to evaluate the effects of different potential transpiration rates and different irrigation management strategies on the overall triggered irrigation system. In both experiments, irrigation was controlled by a closed loop irrigation system linked to tensiometers. Collected experimental data were analyzed using the HYDRUS 2D/3D code. A system-dependant boundary condition, which initiates irrigation whenever the matric head at a predetermined location drops below a threshold, was implemented into the code. The model was used (a) to evaluate collected experimental data, and then (b) to optimize the operational parameters for two hypothetical soils. The results show that HYDRUS 2D/3D predictions of irrigation events and matric heads are in good agreement with experimental data, and that the code can be used to optimize irrigation thresholds and water amounts in an irrigation pulse to increase the efficiency of water use.

MILLIMETRE WAVES; A NOVEL AND PROMISING REMOTE SENSING TOOL FOR SOIL SUB-SURFACE MAPPING: FIRST STEPS

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Millimetre and submillimetre waves (the latter are also known as Terahertz waves) are the electromagnetic radiation across the 1-10mm, 30-300GHz and 0.1-1mm, 0.3-3THz wavelength/frequency ranges, respectively. Both, microwave and quasioptical techniques are used for their transmission. Remote sensing windows in the millimetre waves reside between 30GHz and 40GHz, 75-110GHz, as well as around 140GHz, with atmospheric attenuation as low as 0.4dB/km at 94GHz. Millimetre, submillimetre and THz waves may show rotational, vibrational and deformation spectra of soil constituent molecules. Remote sensing of soils is currently performed using a combination of methods: passive hyperspectral remote sensing in the VIS-SWIR-NIR-TIR ranges, with maximum penetration depth of 50µm, and active microwave – GPR – and low frequency electromagnetic - FDEM - ground penetrating measurements and, which are expensive and labour intensive and provide limited resolution and coverage. Millimetre waves have not been broadly applied for soil research, particularly not in Israel. Several researches do exist, however, which show the potential for a cost-effective resolution-penetration depth trade-off, providing a more comprehensive tool palette for soil research. Preliminary results have shown the effects of surface roughness, moisture-content profile, sub-soil penetration and layered structure, on reflectance measurements. The research plan includes laboratory magnitude and phase measurements at different wavelengths and polarisations aimed at finding the correlation between moisture content/soil fabric (particle size, crust, dispersion, compaction) and backscattering. In parallel, measurements in other methods will be performed and the results compared. This will yield an extremely wide spectral coverage, as well as a better resolution-penetration-depth combination.

OVERVIEW OF ELECTROMAGNETIC METHODS FOR EVALUATION OF SOIL WATER CONTENT AND SALINITY

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Electromagnetic (EM) measurements of the soil electrical properties began at the end of 19th century. The soil's effective electrical conductivity (σ_{eff}) and dielectric permittivity (ε_{eff}) are two macroscopic properties determined by the volumetric fractions and by the intrinsic properties of the soil's solid, liquid and gaseous phases and their geometrical and interfacial features. The low-frequency (Hz to kHz) electrical conductivities of soils (σ_{DC}) are in the range of 0.001 to 2 dSm^{-1} and their high-frequency (MHz to GHz) dielectric constants (ε_{∞}) posses values of 3 to 50. The low-frequency (LF) electrical conductivity (σ_{DC}) and the high-frequency (HF) dielectric constant (ε_{∞}) are the more commonly measured and modelled electrical properties, as they serve for evaluating the soil water content and soil solution salinity. Thus, the scope of this lecture is limited to EM methods measuring the "static" (apparently frequency-invariant) features of these two properties and not to their frequency response. We will present the common methods for measuring the soil's LF σ_{eff} and HF ε_{eff} and discuss in brief their merits and limitations.

The three common methods for measuring the soil LF (Hz to kHz) electrical conductivity are: 1. Direct (contact) electrical resistivity, ER, based on injecting current through two-electrodes and measuring the voltage drop in two other electrodes via four-probe arrays; 2. Electromagnetic induction (EMI) based on inducing a magnetic field in the soil via a transmitter and measuring the secondary magnetic field via a receiver antenna; and 3. Time Domain Reflectometry (TDR) based on measuring the attenuation of an electromagnetic wave travelling through a waveguide inserted in the soil. ER operates at various modes, e.g. shaft-mounted four-electrode inserted after pre-augering and, surface arrays (ERT, electrical resistance tomography) and between boreholes, and in a broad range of spatial scales from millimetres to kilometres. EMI devices usually measure to depths from 1 m to tens of meters and the TDR probes are usually about 10 cm long. The commonly used frequency range for the soil σ_{DC} determination in the field is about 100 Hz to several kHz, because at lower frequencies electrode polarization interferes with the readings and at higher frequencies (kilo- to megahertz) the EC is no longer constant at the DC value, but increases with frequency.

The common methods for measuring the soil high-frequency (MHz to GHz) permittivity are (in order of increasing frequencies with some overlaps): 1. Capacitance probes, based on measuring the operating frequency in an oscillator circuit; 2. Impedance probes, based on measuring the reflection coefficient of a standing wave; 3. Ground Penetrating Radar (GPR) based on measuring the propagation velocity of transmitted, EM waves; and 4. TDR based on measuring the propagation velocity of EM waves travelling through waveguides. The in-situ capacitance, impedance and TDR probes are all few cm-long and GPR can operate in resolutions of few centimetres to tens of meter for GHz to MHz frequencies, from either above soil surface or between boreholes.

INVESTIGATION OF THE RELATIONSHIP BETWEEN SOIL HETEROGENEITY AND FLOW PROCESSES IN THE VADOSE ZONE

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Understanding the water flow processes beneath the ground surface is highly important due to the availability of these waters to human needs on one hand, and their sensitivity to pollutions on the other hand. The Vadose zone, located between the surface and the ground water, is an area through which all water passes before reaching the aquifer. The flow dynamics in this area are important for agriculture and environmental processes, but are hard to quantify. One reason for this difficulty is the fact that the flow- dynamics often refers to the soil being a single homogenous unit. However, this description is biased and ignores soils heterogeneity. The second reason is the technical difficulty of looking at the processes below the ground surface for a long time, without violation of the natural structure, which can't be imitated in laboratory conditions. The main objective of this research is to investigate the physical heterogeneity of the natural soil in the shallow vadose zone and to relate soil heterogeneity and flow processes.
The research site is an Avocado orchard located in the southern area of Hof HaCarmel in Israel, where Hamra soil is common. In the first stage, we preformed dye-tracing experiment in order to reveal the actual water flow path. Below the surface, in the colored area and around it, various sensors (around 70 time domain reflectometry (TDR), tensiometers, and thermocouples) were inserted into the soil in high resolution, connected to a data logger located at the surface. Two controlled experiments were carried out – sprinkling and flooding experiments – in order to investigate the water flow dynamic under a known top boundary condition. By collecting a high frequently (every 20 minutes along one year and higher temporal resolution during controlled experiments) water content data and information about destructive soil samples, collected from the profile for laboratory analysis, we hope to learn more about the water flow dynamics in natural soil. Simultaneously, the collected data is compared to data from water flow models with heterogeneous and averaged soil properties.
So far, the soil analysis showed mild heterogeneity in soil hydraulic parameters, as predicted. In addition, the dye tracing experiment have shown preferential flow paths, apparently related to roots pathways. Preliminary comparison of water content data from the field to model data have only proved the difficulty of water flow processes description while taking in consideration soil heterogeneity in the profile.

RETRIEVAL OF SURFACE ROUGHNESS PARAMETERS OF BARE SOIL FROM THE ERS-2 SAR DATA

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Small soil roughness (with root mean square (RMS) height *h* less than 1cm) is typical for many natural surfaces. It is an important feature controlling how the rainfall distributes among runoff, evapotranspiration and infiltration. In turn, the rainfall allocation determines surface water content and energy balance; governs the partitioning between latent and sensible heat; and influences the yield potential of agricultural fields.

However, the ground evaluation of *h* is a time and labor consuming process. At the same time, active microwave remote sensing technique allows measurements of the backscattering coefficient σ^0 which is extremely sensitive to the soil surface roughness and water content θ. Therefore, it is possible to employ the satellite data on σ^0 to retrieve values of *h* under known values of θ. The archive ERS remote data have been collected from 1991 and, therefore, they have the potential to fill the void in the available historical ground data on the soil surface roughness.

Our study showed that under arid conditions the surface soil water content stays constant at its minimum value during the whole period of drought. This allowed us to formulate a mathematical model using the remote sensing data on σ^0 and the known values of θ during the drought to retrieve the values of *h*. The measured soil surface water content θ was used for the evaluation of *h*. To validate the output, values of *h* determined by a ground automated laser system were compared with the roughness height determined by the remote method.

The presented method allowed retrieving parameters of small surface roughness by using the archive single-channel ERS-2 SAR images. It was shown that in the range of *h* from 0.1 to 1.0 cm, the dependence of the retrieved values of *h* on the measured σ^0_{vv} could be fitted with high precision by an exponential function. Error analysis of the proposed algorithm showed, in particular, that the relative determination error of *h* did not depend on its value.

Analysis of daily variations of surface θ during the dry period confirmed that θ remained generally constant (1±0.1 % for sand and 2.3±0.2% for loess) at the time of the satellite survey. This phenomenon, which is characteristic for the arid conditions of the studied area, eliminates the need in laborious measurements of θ for the retrieval of *h*. The values of *h* retrieved during both dry and wet periods showed a fairly good agreement with the ground measured values from both sand- and loess-soil test sites. This corroborates the validity of the proposed method and its assumption about stability of *h* in time.

The study determined that only several tens of pixels were required for obtaining a representative mean value of *h* for the investigated visually homogeneous sandy and loessy

soils (typical for the northern region of the Negev desert). Although the study was concentrated only on sandy and loessy soils, the presented method can be applied to any type of soil under the arid environment. The numerical analysis demonstrated very low sensitivity of σ_{vv}^{0} to the correlation length *l* in the ranges of validity $0.1 \le h \le 1.0$, $2.0 \le l \le 20$ which also corroborated the usability of this model for any type of soil with no additional error.

SOIL DEGRADATION MONITORING BY ACTIVE AND PASSIVE REMOTE-SENSING MEANS: EXAMPLES WITH TWO DEGRADATION PROCESSES

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In this presentation we will review the recent developments in the monitoring of soil degradation processes using a passive remote-sensing method (diffuse reflectance spectroscopy and its deviation factors) and active remote-sensing tools such as ground penetration radar (GPR) and frequency domain electro-magnetic (FDEM). We have limited our review to two important degradation processes: structural crust, and salinity.

Recent work has shown that a hyperspectral (narrow bands) approach combined with active remote-sensing means (FDEM and GPR) can be used to provide detailed 3D maps of soil salinity status in crop lands. Such a map could improve our understanding of salinization mechanisms and salt sources, towards improved drainage-system planning and management. Another pronounced soil-degrading hazard is the formation of structural crust in subsequent rainstorm events that decreases soil infiltration, accelerates water runoff and raises the potential for soil erosion. Studies show that the spatial distribution of soil infiltration can be assessed by using spectral information from bare soils via both field and laboratory means. In discussing the above soil degradation aspects, this review should serve as a precursor for future innovative studies of soil degradation processes as well as to open up a new frontier for soil preservation using hyperspectral technology

ET COMPONENTS INVESTIGATED INDIVIDUALLY - TESTING THE TWO SOURCE MODEL IN AN ARID VINEYARD

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One of the less explored questions regarding evapotranspiration (ET) in crops is how to account for the individual contributions of surface evaporation (E) and crop transpiration (T). This is particularly relevant in row crops, where management practices in the interrow can significantly affect the total evapotranspiration flux.

This research aims to quantify individual ET components in a vineyard situated in an arid area. Firstly, by investigating two novel technologies developed to determine soil evaporation independently: a micro-Bowen-ratio system, and soil heat pulse probes. Secondly, by testing the ability of the Two Source Model (TSM) to accurately separate E and T by comparing model outputs to measured fluxes. The TSM is a well tested model that gives good estimates of ET, and is based on the surface energy balance; using meteorological data and remotely sensed temperature and leaf area data as inputs. The model computes ET by iterative calculations using two sources: canopy transpiration and soil evaporation, but the accuracy of the individual components E and T have not been validated. Field measurements include: 1) Meteorological measurements: solar radiation, air temperature and humidity, wind speed and direction, 2) Flux measurements: net-radiation (3 locations), soil heat flux (5 locations), ET and sensible heat flux (eddy covariance), E (micro Bowen ratio systems and heat pulse probes), 3) Temperature measurements: surface (infrared thermometers) of the canopy, the soil (interrow and below vine), and the entire vineyard (soil and canopy). Initial results show interesting dynamics in the energy fluxes along the cross-section between vine row and interrow.

DETECTING AND MONITORING SOIL SALINITY IN AGRICULTURAL LANDS USING COMBINED HYPERSPECTRAL DATA AND CHEMICAL MEASUREMENTS

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Salinity is an important impediment to crop growth and an indicator of soil fertility. It occurs predominantly in semi-arid regions on irrigated agricultural land. To quantify soil salinity dynamics through amelioration efforts, new methods are needed to precisely and cost-effectively assess salinity. In this study we developed a remote sensing method to assess and monitor soil salinity in agricultural fields using state-of-the-art remote sensing means in combination with chemical soil analysis.

In this research we mapped soil salinity in agricultural lands based on data acquired by air-borne (AISA sensor) and space-borne (Hyperion sensor) imaging spectroscopy. The air and space data was calibrated with ground truth spectral and chemical data.

The research covers a few agricultural fields in two different areas: Syr-Daryo in Uzbekistan and Jezre'el Valley in Israel. Those areas are characterized by increasing soil salinity over the years, which results in deterioration of the soil structure and infiltration rate. The main causes of salinization in those areas are intensive irrigation followed by capillary rise of water. Those are combined with hot and dry summer weather which causes intensive evaporation and formation of salt crusts in some cases. Local factors, such as proximity to waste water reservoirs and poor drainage systems, contribute to increase the soil salinity even more. In each test area soil sampling was carried out. The samples were measured with an ASD spectrometer and chemically analyzed for electrical conductivity (EC) and main ions content. The best results were achieved when EC measurements were correlated to soil reflectance continuum removed spectra. The EC data and the measured spectra were correlated utilizing a multivariate calibration analysis using Partial Least Squares Regression (PLS). The most dominant spectral features contributing to the correlation were then extracted from the primary statistical model, creating a reduced multispectral model from the hyperspectral data. The final model was applied on the hyperspectral images in order to produce a thematic map of the surface containing predicted EC values per-pixel. In addition, the chemical measurements revealed high correlation between surface EC and root-zone EC (30cm depth). Using this information a sub-surface salinity map was generated by applying the correlations' straight line equation on the surface EC thematic map. The generated maps were found to be in good agreement with maps based on chemical and other data, produced in this study and in former studies.

The results indicate that chemical methods which are correlated with remote sensing methods provide a correct picture of soil salinity. A spectroscopy based EC prediction model can be built and reduced to relatively low spectral resolution. A model of this kind can be applied to air-borne and space-borne hyperspectral imagery in order to map soil salinity in a fast, accurate and cost effective way.

SPECTRAL CHANGES AT VIS-SWIR REGION OF BURNED SOILS AS A TOOL FOR MONITORING HEAT INDUCED SOIL MINERALOGICAL CHANGES

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Wildfire might cause mineralogical changes in soil minerals which are mostly irreversible. The changes are a function of temperature and heating duration. Soil spectroscopy techniques was found to be successfully in many applications, such as soil attribute analysis, soil mineral identification and general soil description.
We conducted a controlled laboratory study in order to investigate, systematically, the relation between the spectral changes and the soil mineralogical changes. Five Israeli forest soils have been heated, using laboratory furnace, from 150ºC to 1000ºC (50ºC intervals) for 20, 120, 240 and 480 minutes. In addition, standard minerals (Goethite, Hematite, montmorillonite, illite, kaolinite and calcite) were included to track a variety of changes. After cooling and exposure of soils and minerals to ambient air, for minimum of 48 hours, the materials were measured for reflectance at 350-2500nm (2151 bands) using an ASD field-Pro spectrometer. Four types of spectral changes were observed: (1) changes in the VIS-NIR region, related to iron oxides transformations; (2) changes in NIR-SWIR region, related to soil ability to absorb water after heat treatment; (3) changes in the SWIR region, related to dehydroxilation and breakdown of minerals' structure and decarbonization of soil calcites; (4) changes in the overall brightness (albedo). The spectral changes in the entire VIS-SWIR region were documented and explained based on the thermodynamics of the soil constituents. These changes were used to develop spectral indices for estimating the temperature that the soil experienced.

DEVELOPMENT OF A GIS DATABASE TOOL FOR MANAGING SOIL SALINITY PROBLEMS IN IRRIGATED FIELDS IN THE JEZRE'EL VALLEY, ISRAEL

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The aim of this presentation is to show the utility of GIS for monitoring soil salinization in agricultural fields. This database consists of parameters that affect soil salinization. The GIS database was developed as part of a large project "Recognition, quantification and prediction of soil salinization hazards as a result of the engineering activities in the Jezre'el Valley", during 2008-2010. The main objective of the project was to asses the changes in the groundwater regime, resulting from engineering activities and to predict soil salinity problems.

This Spatial data is stored in the file geodatabase and consists of free feature dataset, Drainage Network Systems, Soil and Water Salinity Survey, Hydrology System containing logically related feature classes tables and photos.

Drainage Network Systems is composed of more then 80 drainage systems that were installed in Jezre"el Valley since the early 70's. Each drainage system was converted to digital image format. Each polyline represents an underground drainage pipe.

Soil and Water Salinity Survey is composed of 3 point feature class layers. Piezometer layer represents the location of groundwater observation wells, hyperlink to the image of the observation well log, and the table containing properties of each well. This layer is related to groundwater level and water salinity measurements and to the pumping test results tables. Soil salinity layer shows the location of each soil sampling point. The related tables inform us about the chemical properties of the soil. The Survey well layer presents description of more than 200 wells that were drilled in the Jezre"el Valley since the early 70's. This layer is linked to the images of the survey wells log. The layer of the lithological cross-section polylines shows the lithological structure of the upper soil layer in the Jezre"el Valley. Its content links to the images of the lithological cross-sections. Hydrology System represents reservoir polygons feature, watershed polygon, river network, DTM, Radar rain grids.

MONITORING OF PORE WATER FLOW USING LOW-FREQUENCY ELECTRICAL METHODS

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Self-potential (SP) and induced polarization (IP) are two geophysical methods, one passive and one active, that can be used to bring information regarding the transport properties of porous media and the presence of contaminants dissolved in the pore water or immiscible fluid phases (e.g., wetting or non-wetting NAPLs and DNAPLs for instance). I will start by providing a general and unified theory for both SP and IP phenomena and Iwill show that these two methods are fundamentally the two sides of the same coin. This theory accounts for the pore size distribution of the porous materials. In addition to the physics, I will discuss new algorithms to perform the time-lapse tomography of SP sources and IP parameters. I will discuss the application of these methods to a variety to the detection of preferential flow paths in the subsurface and permeability tomography.

SPECTRAL INDUCED POLARIZATION (SIP) MEASUREMENT OF NAPL CONTAMINATED SOILS

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The potential applicability of spectral induced polarization (SIP) as a tool to map NAPLs (non aqueous phase liquids) contaminants at the subsurface lead researchers to investigate the electric signature of those contaminant on the spectral response. However, and despite the cumulative efforts, the effect of NAPL on the electrical properties of soil, and the mechanisms that control this effect are largely unknown. In this work a novel experiment is designed to further examine the effect of NAPL on the electrical properties of partially saturated soil.
The measurement system in use is the ZEL-SIP04 impedance meter developed at the Forschungszentrum Julich, Germany. The system accurately (nominal phase precision of 0.1 mrad below 1 kHz) measures the phase and the amplitude of a material possessing a very low polarization (such as soil). The sample holder has a dimension of 60 cm long and 4.6 cm in diameter. Current and potential electrodes were made of brass, and while the current electrodes were inserted in full into the soil, the contact between the potential electrode and the soil was made through an Agarose bridge. Two types of soils were used: pure quartz sand, and a mixture of sand with pure Bentonite. Each soil (sandy or clayey) was mixed with water to get a saturation degree of 30%. Following the mixture with water, NAPL was added and the composites were mixed again. Packing was done by adding and compressing small portions of the soil to the column. A triplicate of each mixture was made with a good reproducible bulk density. Both for the sandy and clayey soils, the results indicate that additions of NAPL reduce the real part of the complex resistivity. Additionally, for the sandy soil this process is time dependent, and that a further decrease in resistivity develops over time. The results are analyzed considering geometrical factors: while the NAPL is an electrical insulator, addition of NAPL to the soil is expected to increase the connectivity of the water phase, and therefore a decrease in the real part of the complex resistivity occurs.

FIELD SCALE WATER FLOW CHARACTERIZATION

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An integrated approach was used to determine the physical properties and water flow characteristics of a 28.3 ha field, designated for studying the fate and transport of nutrients, salts and microorganisms under land application of dairy wastewater. The electromagnetic induction technique served to study the spatial variability of the physical properties in the field and was used to direct soil sampling. The laser diffraction technique was employed to generate detailed information on soil particle size distribution at each sampling site. This information in conjunction with bulk density served as input for models, predicting the hydraulic properties of the soil profile. Numerical simulations based on the predicted properties demonstrate the water flow and solutes transport at different location of the cultivated field.

HYDROLOGICAL FLUXES OF A SEMI-ARID SEALED SYSTEM AND THEIR RELATION TO VEGEATATION PATTERNS

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Understanding the mechanisms underlying hillslope soil moisture dynamics and vegetation patchiness remains a current challenge in hydrology, especially in ungauged watersheds. In dry areas, these mechanisms include the formation of surface seals, that although directly affects infiltration and evaporation fluxes, researchers usually disregard its development when predicting soil moisture patterns. The role of these seals in shaping spatial and temporal patterns of soil moisture, considered as the primary limiting factor for dry area plant distribution, is still an open research gap. At the LTER Lehavim site, in the center of Israel (31020' N, 34045' E), a typical hillslope (0.115 Km^2) was chosen offering different aspects and a classic geomorphologic banding. Annual rainfall is 290 mm, the soils are brown lithosols and arid brown loess and the dominant rock formations are Eocenean limestone and chalk with patches of calcrete. The vegetation is characterised by scattered dwarf shrubs (dominant species *Sarcopoterium spinosum*) and patches of herbaceous vegetation, mostly annuals, are spread between rocks and dwarf shrubs. An extensive spatial database of soil hydraulic and environmental parameters (e.g. slope, radiation, bulk density) was measured in the field and was interpolated to continuous maps using geostatistical techniques and physically-based models. To explore the effect of soil surface sealing, the *Mualem and Assouline* (1989) equations, describing the change in hydraulic parameters resulting from soil seal formation, were applied explicitly in space to the entire hillslope. Two simple indices were developed to describe local evaporation rates and the contribution of water from rock outcrops to the downslope soil patches. This spatio-temporal database was used to characterise 1187 cells serving as an input to a numeric model (Hydrus 1D) solving the flow equations to predict soil water content at the single storm and the seasonal scales. Predictions were verified (R^2=0.84) by sampling gravimetric soil moisture at 63 random locations, during three consecutive storms in the 2008-09 rainy season. The emerging soil moisture patterns for a sealed and un-sealed system were found remarkably different, with the sealed system retaining higher and more evenly distributed soil moisture values, an effect augmented during drying intervals. Spatial Association analysis found the vegetation – soil moisture relation to be positively correlated only in hillslope areas with high soil moisture content. In drier areas this relation weakens and other factors dominate vegetation distribution.

WATER CONTENT DISTRIBUTION AND ITS RELATIONS WITH PLANTS UP TAKE PROCESS

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The importance of the water optimation has an integral part of the water usage in agriculture inspired in part by attempts to manage the root zone for maximum crop production. Therefore, the up take process will be completely described in order to maximize the amount of water consumed by the plant's roots. Understanding it, we will analize the vadose zone as the zone playing main role in many aspects of hydrology, including infiltration, soil moisture storage, evaporation, plant water uptake, groundwater recharge, runoff and erotion.
In this research, the main goal is to demonstrate the relation between the water content and its spatial distribution during the plant's uptake process. For this we will define several approaches to show those phenomena that can be consider like secondary objectives to strength our hypothesis.
Electrical resistivity tomography (ERT): Technology used to measure the specific resistivity / conductivity in a specific electrode during a determinate period of time. The method of use is 9 normal readings and 1 reciprocal reading daily, lasting the first nearly 90 minutes each and the last around 8 and a half hour.
Time domain tomography (TDT): Tool used to obtain constant readings of the interest values in our system. The parameters that we were interested in are: volumetric water content in range from 0% to 100% with a resolution of 0.06 % and a typical accuracy of ± 2 %, temperature stability, soil electrical conductivity, address of the sensor, date and hour, and type of reading, average or sample.
Echo probes: 5 simultaneous sensors placed in 3 barrels in the following distribution. The values collected for each of them will be: electrical conductivity, temperature, bulk rate, water content, soil moisture, etc
Hydrus 3D® and r3t®: Computational software packages used to model, analyze, inverse and interpret the information collected by the three previous quoted technologies. In r3t we will transform the resistivity values collected to volumetric water content though a process known as inversion.
The experiment had been successfully done at ARO (Volcani center). Now we are in the stage of processing all the collected data through the various methods previously described. We have started with a preliminary inversion of the data to verify that the readings taken were in the expected ranges. The complete analysis of all the information collected is done according to the Gantt diagram provided in the presentation.

ADVANCES IN HYPERSPECTRAL REMOTE SENSING OF VEGETATION AND AGRICULTURAL CROPS

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The overarching goal of this keynote lecture will be to provide a "state-of-art" on the advances made in using hyperspectral narrow-band data when compared with multi-spectral broad-band data in characterizing, modeling, and mapping vegetation and agricultural crops. Hyperspectral data can provide significant improvements in spectral information content when compared with traditional broad-band analyses in study of vegetation and agricultural crops as demonstrated by a number of thoughtful investigators in studies such as in: (a) detecting plant stress, (b) measuring chlorophyll content of plants, (c) identifying small differences in percent green vegetation cover, (d) extracting biochemical variables such as nitrogen and lignin, (e) discriminating land-cover types, (f) detecting crop moisture variations), (g) sensing subtle variations in leaf pigment concentrations, (h) modeling biophysical and yield characteristics of agricultural crops, (i) improving the detection of changes in sparse vegetation, and (j) assessing absolute water content in plant leaves.

The multi-spectral broad-band remote sensing has been recognized as a reliable method for estimating various biophysical and biochemical vegetation variables. However, broad-bands have known limitations in providing adequate information on properties such as crop growth stage identification, crop type differentiation, generation of agricultural crop statistics, forest type and species identification, characterizing complex-forest versus non-forest interactions, and detail mapping of land cover classes of interest to diverse scientific and other user communities. Also, for example, broad-band vegetation indices (VIs) saturate beyond a certain level of biomass and leaf area index (LAI). VIs typically increase over an LAI range from 0 to about 3 to 5 before an asymptote is reached. These limitations will be discussed in detail during the lecture by demonstrating how hyperspectral narrow-bands and the indices derived from them can significantly improve: (a) information content of the vegetation and agricultural crop biophysical and biochemical quantities, (b) species type differentiation, and (c) classification accuracies of the land use\land cover classes.

However, an overwhelming proportion of the hyperspectral narrow-bands can be redundant for any one given application. So, it will be extremely important to identify and remove the redundant bands from further analysis to ensure best use for resources and to overcome the curse of high dimensionality or Hughes phenomenon. Through a comprehensive analysis by many leading researchers, we identify 28 optimal hyperspectral narrow-bands, in 400-2500 nanometer range, that are best suited in the study of vegetation and agricultural crops. The wavebands were identified based on their ability to: (a) best model biophysical and biochemical properties, (b) distinctly separate vegetation and crops based on their species, type, structure, and composition, and (c) accurately classify vegetation and crop classes.

The lecture will also highlight the computation and use of various hyperspectral vegetation indices (HVIs) in studying and determining most valuable wavebands in study of vegetation and agricultural crops. The specific importance of each of the wavebands to specific biophysical and biochemical properties of vegetation and agricultural crops are also highlighted. Typically, there is more than one waveband for each crop variable. For example, biophysical and yield are best modeled using wavebands centered at 682 nm, 845 nm, and 1100 nm. Similarly, moisture sensitivity in leaf\plant by several wavebands centered at 915 nm, 975 nm, 1215 nm, 1518 nm, 2035 nm, and 2260 nm. The 28 optimal wavebands will allow us to compute 378 unique hyperspectral two band vegetation indices (HTBVIs). Overall, there is clear evidence that the combination of the 28 identified bands and various HVIs computed from them will suffice to best characterize, classify, model, and map a wide array of vegetation and agricultural crop types and their biophysical and biochemical properties.

NEW PLANT-BASED FEEDBACK IRRIGATION TECHNIQUES FOR INCREASING WUE OF CROPS

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Irrigation is essential for agricultural production in arid regions where rainfall is inadequate to sustain crop growth. According to the FAO, only 40% to 60% of the water is effectively used by the crop; the remaining water is lost, either through evaporation, runoff, drainage, or deep percolation into the groundwater.

Irrigation scheduling is the primary tool for improving water use efficiency and raising yields, while minimizing soil and groundwater pollution. To date, there is no tool other than in-situ sensors (tensiometers, TDR etc.) that can help farmers to determine irrigation quantities and scheduling. Nevertheless, these sensor readings do not represent the soil water status in the field because they correspond to a small volume and their operation range is limited, and because of the spatial variability of the soil hydraulic characteristics. Similarly, calculation of irrigation quantities from meteorological data requires crop-specific transformation function. Lysimeters, on the other hand, offer precise data on water requirements of specific crops, yield response to various environmental conditions, horticultural management parameters and drainage water quality. However, as far as we know, they have been used for research only.

Two plant-based automated high frequency irrigation techniques were applied in field crops, grown in the Southern Arava region, Israel. The first technique utilized hourly measurements of the evapotranspiration (ET) in an in-situ representative weighing lysimeters. The irrigation frequency was 7 d-1, and its quantity was set to 120% from the measured ET. The second technique supplies water to the crops, daily in a varied frequency set according to their demand. We have developed buried Tensio-dripper sensors, wrapped in Geo-textile. This media encourages a massive root growth herein, and therefore, root density in this media is high. Reading the matric potential in this media yielded better indication of water availability to the plants. Soil water variables, such as water storage, the EC and the quantity of the drainage water, and root-zone matric head were monitored. Those variables and the ET were also monitored in control plots, which were irrigated daily according to the local irrigation practice.

The automated irrigation, applied in both techniques, was found to reduce both irrigation and drainage water quantities, while sustaining the same yield and ET values. Many growers over-irrigate due to a general lack of means for measuring crop water use. The investigated tools were found to increase water use efficiency of field crops while simultaneously decreasing agrochemical use and soil contamination.

CHARACTERIZATION AND MODELING WATER INFILTRATION AND REDISTRIBUTION IN REPELLENT SOILS BY MOMENT ANALYSIS AND ARTIFICIAL NEURAL NETWORKS

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In many arid and semi-arid regions, low quality water (e.g., treated wastewater and sewage effluent) serves as an important water source for agriculture. Due to the high concentration of nutrients and organic substances, prolonged irrigation with such water alters the soil properties. Soil's wettability is one of the altered properties. The decrease of soil wettability (water repellency) affects the water infiltration rate and its flow pattern in the soil profile, and has consequences on plant growth, surface and subsurface hydrology, and irrigation design. The presented work addresses both the understanding of these processes and suggests a method for their modeling.

Water flow in the soil profile during the wetting and subsequent redistribution was experimentally studied by monitoring the reflected light from a transparent flow chamber in which water-repellent and similar wettable soils were packed in a uniform manner. Water was applied to the soil as on- and sub-surface point source at different rates. The experimental results demonstrated that the water flow patterns, i.e., general shape and size of the wetting plume as well as the internal moisture distribution, were significantly different between wettable and water repellent soils. The bulb-like shape plume in the wettable soil was replaced by a long and narrow, finger-like plume in the water repellent soils. While moisture content varied monotonously within the wettable soil plumes (gradually decreasing from the soil surface toward the wetting front), a non-monotonous moisture content variation was observed for the water repellent soils. A moisture accumulation behind the sharp wetting front (noted as saturation overshoot) was observed. Such non-monotonous moisture content variation has been associated with unstable flow in soils. Differences between the wettable and water repellent soils were also observed in the moisture content distribution along horizontal cross sections. The plumes shape and size and the internal moisture content distribution varied with water application rate as well.

Water flow in the different soils was characterized by the moment analysis method. The zeroth moment stands for the total moisture volume in the plume, and the first and second moments relate to the center of mass and spatial variances, respectively. The moisture plume shape and internal moisture content distribution were successfully represented by ellipses that were determined on the basis of these moments. It was unexpectedly found that a single cumulative probability curve represents the corresponding fractions of the total added water within different ellipses for all soils and water application rates.

The potential of artificial neural networks for modeling soil water dynamics in water-repellent and wettable soils was examined. Three different architectures of artificial neural networks models were tested for laboratory and synthetic data. One-dimensional self-organizing maps

(SOM) networks were successfully used for mapping the moisture content distribution in the transition zone of the wetting plumes, where the spatial locations of artificial neurons of SOM are indicative of intrinsic statistical feature of the input patterns, and also preserve the spatial structure inherent in the soil moisture distribution. Due to the limitation of the unsupervised SOM hybrids of multilayer perceptrons (MLP) or modular neural networks (MNN) with the SOM models were created and demonstrated to predict the moisture contours for both wettable and water-repellent soils. The MLP and MNN networks were also successfully applied to predict the spatial moments of the water content distributions. The artificial neural networks model and hybrids presented has been demonstrated as a tool for modeling water dynamics in complex systems, where mechanistic-model based prediction is not available.

Sensing & Control Systems

Theme Heads

Rafi Linkers & Avital Bechar

ROOT AND RHIZOSPHERE VISUALIZATION BY LASER-INDUCED FLUORESCENCE IMAGING

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Developing new, non-invasive methods that would enable continuous monitoring of spatial and temporal variations of physical and chemical parameters in the rhizosphere *in situ* is required in order to improve our understanding of the interactions between roots and their immediate environment. In this work we present the use of laser-induced fluorescence imaging for visualizing processes that occur in the rhizosphere.

Several studies have shown relationships between root fluorescence, root status (active vs. dead) and nutrient uptake. The rhizosphere also interacts with UV radiation, for instance as a result of the exudation of fluorescent compounds by the roots. In order to visualize changes in the root activity and in the rhizosphere, we used short pulses from a Nd:YAG Q-switched laser to induce fluorescence, and an intensified gated CCD (ICCD) camera to capture the weak fluorescence signal. Furthermore, by varying the delay between the laser pulse and the camera activation, we were able to obtain time-resolved fluorescence profiles for each of the pixels in the image. Analysis of the amplitude and of the temporal evolution of the fluorescence signal provides a wealth of information about the root and its surroundings.

ESTIMATION OF SEMI-ARID VEGETATION PARAMETERS FROM SYNTHETIC APERTURE RADAR DATA

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This work presents the analysis of the capability to use the radar backscatter coefficient in semi-arid zones to estimate the vegetation crown in terms of Leaf Area Index (LAI). The research area is characterized by the presence of a pine forest with shrubs as an underlying vegetation layer (understory), olive trees, natural grove areas and eucalyptus trees. The research area was imaged by an airborne RADAR system in L-band during February 2009. The imagery include multi-look radar images. All the images were fully polarized i.e., HH, VV, HV polarizations. For this research we used the central azimuth angle (113°). We measured LAI using the ΔT Sun Scan Canopy Analysis System. Verification was done by analytic calculations and digital methods for the leaf's and needle's surface area. In addition, we estimated the radar extinction coefficient of the vegetation volume by comparing point calibration targets (trihedral corner reflectors with 150cm side length) within and without the canopy. The radar extinction in co- polarized images was ~26dB and ~24dB for pines and olives respectively, compared to the same calibration target outside the vegetation. The variability among corner reflectors in the open was +/- 3dB.

We used smaller trihedral corner reflectors (41cm side length) and covered them with vegetation for measure the correlation between vegetation density, LAI and radar backscatter coefficient for pines and olives under known conditions.

Reversed correlation between the radar backscatter coefficient of the trihedral corner reflectors covered by olive branches and the LAI of those branches was observed.

The correlation between LAI and the optical transmittance was derived using the Beer-Lambert law. In addition, comparing this law's principle to the principle of the radar backscatter coefficient production, we derived the equation that connects between the radar backscatter coefficient and LAI.

A COMPUTER VISION ALGORITHM FOR NAVIGATION OF AN AUTONOMOUS SPRAYER IN PEPPER GREENHOUSES

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The essential process of pest control and chemical application of nutrients is one of the most important processes in any agricultural production. Nevertheless, the application requires human resources; it is time-consuming task and exposes the operators to the danger of contamination with hazardous chemicals. Integrating *autonomous* robots and *machinery* in expensive labor, monotonous and hazard agriculture tasks has accelerated in the recants years. *An autonomous robot* provides an elegant solution in many cases. This research, relies on that motivation, focus on the development of a navigation procedure for autonomous sprayer in Sweet peppers greenhouse. An image processing algorithm for an autonomous sprayer in pepper greenhouse was developed.

A live video was acquired using a mobile platform that moved along foliage peppers rows in 3 different pepper greenhouses at different times of the day. The platform was equipped with a Microsoft "LifeCam NX6000", DPI 640x480, CCD camera. The camera was tested at different heights (0.2, 0.3, 0.4, 0.5, 0.55 and 0.6 m) and different pitch angles (180°, 225° and 240°).

The system consist an initialization module using classification methods. The initialization module is using supervised learning to determine the best classifying color and texture features for the image analysis.

A two phase research was taken- the training set was acquired first manually and then automatic. In phase one, representative pixels polygons of "*Ground*" and "*Non-Ground*" were manually marked in ***static images***, creating a 74,000 records "Training Set". Three classification methods (C4.5 decision tree, Neural Network and K-means) were implemented in SPSS Clementine 12.0 and compared using 10-fold cross-validation. Performance measures were: 1. Simplicity- the number of features used; 2. Classification accuracy percentage; 3. "Classification reliability", measuring the classification ability to recreate results for different test environments parameters (light, soil, Greenhouse covering, etc).

Best results were achieved by the C4.5 decision tree using 2-5 features (varying depending on the Environment conditions) and resulting 98% correct classification (0.01% false alarms), as compared to neural network classification, which resulted with identical accuracy but used almost all features. K-means used 7 features and resulted in 75% correct classification. Phase two requires autonomous data sampling for training. Forcing camera location at start for automatic data acquisition. Followed by the initialization, classification (Gaussian intersect and C4.5 decision tree methods) was tested for a real time stream video. Performance was evaluated by comparing human and machine path definition for 14 deferent videos (light, soil, camera hight.etc).

Algorithms optimal configuration parameters and performance evaluation was achieved using Human/Machine comparison. System sensitivity analysis results in optimal path recognition with 89.98% accuracy for 50 cm camera height.
Algorithms optimal configuration parameters and performance evaluation was achieved using Human/Machine comparison. System sensitivity analysis results in optimal path recognition with 89.98% accuracy for 50 cm camera height.

EARLY DETECTION OF PLANT INFECTION WITH PATHOGENIC BACTERIA IN TOMATO AND MELON USING THERMAL IMAGING

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Plant diseases cause significant economic losses in agriculture, and coping with them generally requires the use of chemical pesticides, which are expensive and often have negative effect on the environment and human health. Developing methods for early detection of plant disease before it spreads in the field or in the greenhouse are highly desired as they can lead to a substantial reduction of pesticide utilization and yield reduction. The potential of thermal imaging (TI) for early detection of plant diseases was strength in several studies over the years. TI for early detection of plant disease is based on the principle that plant pathogens affect the water balance of infected tissue, which in turn alters its temperature relative to healthy tissue. The use of infrared imaging allows detection of these thermal changes, often before appearance of disease symptoms that can be visualized by the human eye. The present study examines the potential of early disease detection using thermal imaging on tomato and melon leaves infected with two important plant pathogenic bacteria, *Clavibacter michiganensis* subsp. *michiganensis* (*Cmm)*; bacterial wilt and canker of tomato) and *Acidovorax*.*citruli* (bacterial fruit blotch disease of cucurbits), respectively. Experiments done with tomato plants showed consistent temperature increase of leaves inoculated with *Cmm* relative to control leaves. In some cases, these thermal changes were detected before appearance of visible disease symptoms. In the melon *A. citrulli* system we have noticed elevated temperatures in leaves infected with high concentration of the pathogen, relative to control leaves. These results support the idea that TI can be use to detect bacterial pathogens in tomato and melon leaves, thus making of TI promising tool for basic investigation of the studied pathosystems. However, further investigation should be performed to assess whether TI can be used for early detection of *Cmm* and *A. citrulli* in a commercial scale.

ON-LINE MONITORING OF CLOGGING POTENTIAL IN IRRIGATION SYSTEMS

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General clogging in irrigation systems, especially drip irrigation can cause severe problems. Clogging of filters, pipes and drippers affect inequality of water supply and shortage of water to the crops. Clogging situation is caused by interaction of water quality and the surrounding, and these situations are difficult to predict and examine by regular water quality parameters. Clogging often happens in reclaimed water systems, and it creates the need to find parameters that enable to measure and predict clogging hazards.

Clogging Potential Meter

The clogging potential meter (CPM), invented and developed by the Israel Water Works Association (IWWA), enables to evaluate the potential of clogging situations in microirrigation systems. The concept of this instrument is a measurement of the span of time it takes, for examined irrigation water, to cause partial clogging, at a constant flow rate (10 liters per minute), with a differential pressure of 3 m., across a small screen filter (Figure 1). Beside clogging time, the screen net can be examined in order to identify the cause of clogging.

The CPM gives an integrative index of the Clogging Potential Time (CPT). The CPT which is the time that a clogging needs to be built up, has a negative proportion to water quality and the risk of clogging of the microirrigation system.

During the past years, the CPT was found as a reliable parameter, and the instrument is widely used by water companies, filters producers and farmers. Evaluating the clogging potential by the CPM has several advantages:

Clogging potential can be measured by using only one parameter – span of time. Achieving data that is not found in regular water quality analyze.

Real-time data:

Clogging reasons can be detected. Hence, the CPT has great importance, and it will be part of the new standard of irrigation water. CPT of 5 minutes considered to sufficient when using reclaimed water. CPM is also examined now by the ECU as a parameter for filters standardization. However, this method has also several disadvantages:

The apparatus is manual.

The results are random, and there is no information about the situation between checks.

Because of this, it is often difficult to make use with the CPM in modern and intensive agricultural systems.

Automatic CPM:

The IWWA tried for several years to find solution to the described disadvantages of the CPM, and develop instrument that measure the CPT automatically. Self-washed automatic filters at a constant flow rate were combined in several reclaimed water supply systems, and the number of washes was used as a parameter to evaluate the clogging potential. Figure 2 compare both parameters: number of filter washes and CPT measured by the CPM. It is clear that there is a

negative proportion between the tow variables: more filter washes means shorter span of time till the screen net of the CPM is clogged.
The automatic CPM is based on this idea. Constant flow-throw 150 micron filter is connected to a controller that collects data about the back-washes, and enables many opportunities of control and connection. The on-line automatic CPM demonstrates several advantages:
Only 220V and connection to the water system is needed for its operation.
The water that flowed through the CPM can be connected back to the system and there is no waste.
The CPM is turned on and off together with the water system.
SMS is sent every back-wash, contains the time and the span of time from the previous wash.
All data is collected in an EXCELL format, and can be sent by cellular or wire connection.
Information can be sent to several places, and, for example, the farmer and his consultant can have real-time data.
Message is sent whenever the differential pressure on the screen net has not disappeared after 3 continuous washes.
The biggest advantage is the continuity of the operation and the information gained because of it. Water quality changes during the day, and according to the data obtained from the CMP, the farmer can find the best time for irrigation.
During summer 2007, 5 automatic CMP were already operating in 5 different water reservoirs. Data was collected in a central computer in IWWA offices, and the customers were informed whenever water quality became worse. A weekly report was sent to the customers that could also have data about the last back-wash by the cellular.
Automatic CMP does not enable to identify the type of clogging materials (zooplankton, algae, sand, bacterial contamination, etc.). New version of the CMP contains a video camera, and clear photos are sent to the central computer by cellular. Other development directions like water safety and medicine are also checked.

HYDRAULIC ADAPTATIONS UNDERLYING DROUGHT RESISTANCE OF *PINUS HALEPENSIS*

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Drought-induced tree mortality is becoming a major challenge for forests worldwide. Elucidating physiological mechanisms which underlie drought resistance in trees is imperative for understanding forest function. Our objective was to investigate the hydraulic adaptations underlying the ability of *Pinus halepensis*, a key forest tree species in the Mediterranean, to survive the seasonal, routine droughts prevailing in the dry timberline. One hundred 18 months old trees were exposed to 10 different drought treatments, simulating a variety of drought intensities and durations, from full weekly irrigation to only 25% irrigation once in 3 weeks.

At Ψ_l = -2.8 MPa stomata closed, suggesting isohydric stomatal regulation, yet xylem conductivity loss was ~45%, indicating high sensitivity of the xylem to embolism and narrow hydraulic safety margins (merely 0.3 MPa between stomatal closure and PLC50) in comparison to other coniferous species.

The narrow hydraulic safety margins meant that stomata maximized CO_2 uptake by using the full hydraulic capacity of the xylem.

However in trees under extreme drought treatments, stomatal closure reduced CO_2 uptake to ~1 µmol m^{-2} s^{-1}, presumably leading to carbon starvation.

A differential effect of drought intensity and duration was mediated by a strong dependency of the T/ET partitioning ratio on the patterns of water supply, where the larger irrigation doses allowed higher partitioning to transpiration.

Under intense or prolonged drought the root system became the main target for biomass accumulation, taking up to 100% of the added biomass, while the stem tissue biomass decreased, also reflected by up to 60% reduction in xylem volume.

MEASURING SPATIAL AND TEMPORAL DYNAMICS OF WATER IN SOIL AND SOILLESS SUBSTRATES, TO ENABLE PRECISE SCHEDULING OF IRRIGATION APPLICATIONS

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We are implementing commercially-available wireless sensor networks (Decagon Devices, Inc., Pullman, WA) for irrigation management in a variety of ornamental production environments, as microcosms of different horticultural production systems. Ornamental production in the United States varies from extensive field (soil-based) operations that grow large specimen trees and shrubs, to intensive container-nursery and greenhouse operations which typically produce smaller-sized plants in soilless substrates. In many of these environments, irrigation management is a complex decision-making process for the grower, which is typically compounded by a lack of information on daily plant water use, irrigation systems that do not allow flexible management decisions, and a lack of time to make accurate irrigation scheduling decisions. Real-time knowledge of the spatial and temporal dynamics of water movement in these various soil environments is the key not only to making correct daily irrigation management decisions, but also a vital factor in sensor placement, to reduce the overall cost of networks and increase the precision of the data and quality of the information provided to the farmer.

Two case-studies are presented: (a) Irrigation water applications to newly transplanted *Acer rubrum* and *Cornus florida* trees were reduced by 50% in 2010, by monitoring soil volumetric water content (VWC) and only irrigating when VWC <27% (n=4 trees). Since this tree farm is limited by well capacity, this irrigation water allocation was transferred to 3-year-old trees, which would have likely had reduced growth rates if they had not been irrigated, as 2010 was a drought year in Maryland. In the second example (b) a nursery growing *Acer rubrum* in large 120L containers in a pine-bark soilless substrate (pot-in-pot production) measured daily substrate moisture and rain gauge data which were installed to measure irrigation water applications and leaching from replicate trees. Using these data, irrigation schedules were adjusted by the grower on a daily/weekly basis throughout 2010, as the trees leafed out and evapotranspiration increased during summer. The grower used these networks and other real-time sensor environmental data from a weather station to more precisely schedule irrigation applications (typically 2-3 cyclic irrigations of 4-6 minutes per day per block) using his Tucor™ (Wexford, PA) irrigation scheduling system. He was able to do this quickly (<1 hour per day) and easily from his office computer, by extrapolating sensor data received from networks sensing various indicator species, in a range of container sizes from 39L to 173L, by volume.

OVERVIEW OF MID-INFRARED TECHNIQUES AND CHEMOMETRICS FOR SOIL ANALYSIS

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The need for fast and cheap methods that would enable the analysis of a large number of soil samples has been stressed in numerous studies and infrared spectroscopy has long been recognized as one of the most promising techniques. Although the initial works were conducted mainly in the near-infrared (NIR) range, technological achievements in the mid-infrared (mid-IR) range during the last decade are making this spectral range much more attractive and an increasing number of soil studies are conducted using this spectral range. This work presents an overview of three of the mid-IR techniques most commonly used for soil analyses (Diffuse reflectance, Attenuated total reflectance and Photoacoustic spectroscopy), together with the data-processing methods required to analyze such spectra. Current challenges, and in particular transferability of the results and establishment of spectral libraries, are also discussed.

EXAMINATION OF THE SURFACE RENEWAL TECHNIQUE FOR SENSIBLE HEAT FLUX ESTIMATES IN SCREENHOUSES

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Screenhouses are widely used in arid and semi-arid agriculture to protect crops from direct solar radiation and to increase water saving. However, accurate estimation of crop water use under screens is still a challenge. The most reliable method that directly measures evapotranspiration, the Eddy Covariance (EC), is both expensive and complex in data collection and processing. This renders it unfeasible for day to day use by farmers. A simpler alternative is the Surface Renewal (SR) technique which utilizes high frequency temperature readings of low-cost fine-wire thermocouples, to estimate the sensible heat flux. Assuming energy conservation and employing relatively cheap complementary measurements, the evapotranspiration can be estimated. The SR technique uses a structure function mathematical analysis that involves a time lag parameter and provides amplitude and time period of a ramp-like temperature signal. This behavior arises from the detachment of air parcels that have been heated or cooled near the surface and sequentially renewed by air parcels from above. While the SR technique is relatively simple to employ, it requires calibration against direct measurements. The aim of this research is to investigate, for the first time, the applicability of the SR technique in screenhouses. Experiments were carried out in a vineyard screenhouse within which EC and SR systems were deployed, to simultaneously measure sensible heat flux. To optimize the SR operation, seven fine-wire (40 gauge) exposed T-type thermocouples were placed at 3 heights above the canopy and below the screen and an additional thermocouple was placed above the screen. Thermocouple output was continuously recorded at 10 Hz during a period of 11 days. Preliminary results for day time hours revealed temperature ramp amplitudes of up to 0.8 ºC. The ramp time period was found to increase with the time lag chosen for the analysis, and was of the order of tens of seconds. Best linear correlations between EC and SR sensible heat fluxes were obtained for the thermocouple located at 1.15Hc (where Hc is the canopy height), approximately at the mid-height between the canopy top and the screen. Time lags associated with these results were typically larger than those reported in the literature for uncovered plantations.

A NOVEL MEMS-BASED MICROFLUIDIC WATER POTENTIAL SENSOR FOR MONITORING OF WATER STRESS IN WOODY PLANTS AND SOILS

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As a result of warming climates in many of the world's major agricultural regions and consequent freshwater scarcities, there is growing interest in the water use of vegetation as well as the management of water resources and the optimization of water for irrigated agriculture. Understanding the limiting water potentials (Ψ_w) at which plant productivity declines is valuable for agronomists in order to optimize irrigation scheduling and efficiency. Existing instruments measure plant and soil Ψ_w indirectly, and suffer from limitations in their operating range, portability, or cost. Using nanofabrication tools, we are currently developing a novel micro- electro-mechanical system (MEMS)-based microsensor ("microtensiometer") capable of directly measuring plant and soil Ψ_w continuously and with a high degree of precision. The microtensiometer is designed to be embedded in the stems of woody plants and in soils for real-time measurement of Ψ_w. It has the advantage of having a large range of detection (Ψ_w down to -220 atm), low power consumption, small size, and low cost as a result of economies of scale associated with MEMS fabrication. Scalable sensor arrays can be used in conjunction with wireless networks to provide continuous, high-resolution Ψ_w data to GIS centers to aid in irrigation decisions and optimize water resource management for sustainable crop production. Providing high spatial and temporal resolution of plant and soil Ψ_w, the microtensiometer will be a valuable tool for modeling, research, and precision irrigation programs.

BLIND SEPARATION OF INFRA – RED SIGNATURES OF PLANTS

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The described- herein project aims at examining the feasibility of using mid- infra red spectra for remote sensing of plants or chemicals. More specifically, it encounters the problem of identifying IR spectra sources (plants, for example), in a situation where there is no information at all regarding the number of sources, their types and the relative contribution of each of the sources to an IR spectrum comprising of a mixture of signals emitted or reflected from these unknown sources. This situation is typical for remote – collection of data, in cases where it is impossible to have any access to the sources.

To solve this problem, a blind separation attitude, similar to the attitude used in the separation of vocal signals, was demonstrated with model systems containing mixtures of signals from five different plants: fig, oleander, castor- oil plant, poinciana, and mulberry. Two methods for blind separation of the FTIR spectra were tested and compared: a maximum likelihood method without dilution of data points and a geometrical method comprising of dilution of data points using wavelet functions.

It was found that both methods are highly effective in providing the individual spectra of the unknown sources and the mixing matrix. Furthermore, blind dilution of data points seems to significantly improve the quality of separation. A comparison between different families of wavelets was performed, in order to locate the most adequate wavelet functions for the specific task of separating IR signals. In addition, care was given to analyze the effect of random noise as well the effect of partial lack of data on the quality of signal identification.

The implications of the above – mentioned results on remote sensing of crops will be discussed, while outlining the potential and limitations of this method.

DEVELOPMENT OF NANOMATERIAL PLATFORMS AND LAB-ON-A-CHIP TECHNOLOGIES FOR AGRICULTURAL SENSING APPLICATIONS

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Future advances in agricultural productivity are crucial to meet the world's growing population needs. At the same time green systems will be needed to mitigate the environmental impact of expanded scale agriculture, to protect human health, and to bridge climate change impacts. New sensor technologies will contribute by: 1) expanding capabilities for monitoring of soil and water systems for feedback and control, and 2) by providing new tools to scientifically advance the biotechnology approach to improve agricultural production. One key area of research involves lab-on-a-chip environmental monitoring systems for soil, groundwater, and surface water monitoring. These lab-on-a-chip systems enable multi-analyte monitoring in compact, deployable systems based on inexpensive and scaled silicon microfabrication production. As tools for scientific research new sensors promise new advances in our mechanistic understanding or biological systems which can lead to improved cultural practices and biotechnology approaches for production improvement. Lab-on-a-chip systems will also be applied as scientific tools, as will nanomaterial based biosensors. New nanomaterial platforms are being developed and applied to biosensor development and are advancing biosensor capabilities to new levels of performance. Both lab-on-a-chip systems and nanomaterial based biosensors are being used for fundamental agricultural science research in plant, animal, and microbial systems and a wide range of applications will be reviewed.

PHYSIOLOGICAL PARAMETERS OF PLANTS AS INDICATORS OF WATER QUALITY IN A CONSTRUCTED WETLAND

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Increasing demand for water has stimulated efforts to treat wastewater for reuse in agriculture. Decentralized facilities for wastewater treatment became popular as a solution to remote and small communities. These systems mimic natural wetlands, cleaning wastewater as they flow through a complex of filter media, microbial fauna and vegetation. The function of plants in constructed wetlands (CWs) has not been fully elucidated yet. In the research reported here we provide evidence for a new use of plant physiological parameters in CWs as bio-indicators of water quality along the system. There was improved plant performance downstream of the CW as measured by photochemical efficiency, CO_2 assimilation rate, and cell membrane stability. In addition we found evidence for temporal improvement of plant performance, which was correlated to the establishment phase of plants in a newly operating CW. It is suggested that improved monitoring and management of CWs should take into planning consideration the promising potential of phyto-indicators.

APPLICATION OF THE SURFACE RENEWAL TECHNIQUE FOR ESTIMATING EVAPOTRANSPIRATION FROM AN INDUSTRIAL TOMATO CROP

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Reliable and efficient irrigation management requires a good knowledge of evapotranspiration (ET) for the specific agricultural crop. Direct measurement of whole canopy ET can be performed using the Eddy Covariance (EC) technique, which is nowadays considered the most accurate direct measurement. Nevertheless, its relatively complex operation and expensive equipment makes it unavailable for daily use by the farmer. The main purpose of this study is to adapt and apply an alternative cheaper and simpler method for whole canopy ET measurements, namely, the Surface Renewal (SR) technique.

The SR technique belongs to the family of turbulent transport techniques that measure turbulent fluxes within the surface layer. It is based on the measurement and analysis of air temperature ramps resulting from turbulent coherent structures that undergo ejections and sweeps under shear dominated conditions. Air parcels near the canopy are continuously exchanged with new ones descending from the atmosphere above. The temperature rise (drop) for each air parcel during its residence time near (or within) the canopy allows for an estimate of the sensible heat exchange and thus an estimate of the surface sensible heat flux, H (via a weighting factor α). Hence, the SR technique requires high sampling rate measurement of the air temperature signal near or above the crop. Using additional relatively simple measurements of crop net radiation (Rn) and soil heat flux (G), ET can be deduced as the residual of the energy balance, ET = Rn-G-H.

In the present work, sensible heat flux measured by SR (HSR) was calibrated against simultaneous direct measurements of sensible heat flux by the eddy covariance technique (HEC). Calibration results were then used to verify estimates of ET. Experiments were conducted in a large industrial tomato field (canopy height = 0.6 m) at the Hula Valley of northern Israel. The EC system consisted of a three-axis ultrasonic anemometer and an open path infra-red gas analyser, used to measure wind speed, sonic temperature and water vapour concentration, respectively. The SR system consisted of 5 miniature thermocouples (TC) deployed at several vertical levels above and within the canopy. TC installation at 5 different levels was done in order to identify the optimal level under the conditions of the present study. All output signals were recorded at 20 Hz sampling rate. Measurements were carried out during 13 days on August 2010: data of the first six days was used for calibration and the rest 7 days were used for verification.

HSR calculation was based on a structure function transformation of the measured temperature signals (Van Atta, 1977, Paw U et al., 1995) resulting with a temperature amplitude and a time period of temperature ramps. The analysis includes a time lag variable which may be arbitrarily chosen to optimize the system performance. These parameters are

used to calculate a heat flux which then must be corrected by a weighting factor determined by a linear regression between the HSR and HEC.

Analysis of results obtained during the calibration period showed optimal performance, with a maximum coefficient of determination between HSR and HEC of 0.88, for measurement frequency = 10 Hz, analysis time lag = 0.25 s and TC height = 0. 60 m. For these conditions the obtained weighting factor was $\alpha = 3.04$.

The method's performance was tested during a 7-day verification period. Half-hourly values (W m^{-2}) of LSR were regressed against the latent heat flux, LEC, as directly measured by the EC system during the verification period. The regression resulted with LSR = 0.90LEC – 5, (R^2 = 0.89). Hence, the results show that it was possible to calibrate the surface renewal technique for estimating evapotranspiration during the verification period for industrial tomato crop. Additional approaches for SR application that were investigated during this study will also be presented and discussed.

THE GREENHOUSE AS AN OPEN CHAMBER SYSTEM

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Estimates of gas exchanges (CO_2 and H_2O) of a whole canopy are important from ecological, agricultural and other aspects. Yet, the determination of these gas exchanges has not been simple and consequently yielded different approaches. One of the approaches is the open chamber system. In this approach the outside air is continuously introduced by fans into the enclosure and CO_2 and H_2O fluxes are estimated from the product of the airflow rate and the differences in CO_2 and water vapour concentrations, respectively, of air entering and exiting the enclosure. This study attempts to utilize a large enclosure, of the scale of a greenhouse, as on open chamber system to characterize the performance of the system under such a scale. Experiments were done in a greenhouse with an area of 15x22 m^2 in which pepper was grown. It is shown that within the canopy the photosynthetic activity and transpiration change with height, as expected. Furthermore, it is shown both theoretically and experimentally that in the absence of air mixing within the chamber gradients of CO_2 and H_2O develop along the airflow direction inside an enclosure of such a size. The agreement between the experimental and theoretical values with respect to the developed gradients is good. It is shown that in spite of the gradients canopy photosynthesis and transpiration can be estimated with a relatively good accuracy in a large open chamber. For instance, the measured values of canopy photosynthesis, along the day, from the open chamber approach were in good agreement with the mean photosynthesis values obtained from measurements on spatially distributed individual leaves. A less good agreement was observed with respect to transpiration. The transpiration values with the open chamber approach were generally a little lower than those obtained with lysimeters.

REMOTE SENSING IN MICROWAVE AND GAMMA RANGES FOR THE MONITORING OF THE SOIL WATER CONTENT OF THE ROOT-ZONE

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Provision of the optimal soil water content (*W*) during the crop vegetation period is the main condition for obtaining high yields. For monitoring of the soil water content, an integrated remote sensing system comprised of frequency modulated P-band (λ=68cm) scatterometer and gamma ray radiometer (50-3000kev) has been developed. The system was installed onboard of a light aircraft and tested in an irrigated agricultural region of the Negev desert.

Analytical models for both backscattering coefficient ($\dot{R}$) and intensity of the natural gamma radiation (I_s) have been developed for different types of soil with arbitrary vertical distributions of the soil moisture. These models are based on replacing an arbitrary (continuous) vertical distribution of W by a system of discrete homogeneous layers. The values of W at the boundaries of each layer are changed discretely at the transition from one layer to the other.

The backscattering coefficient was calculated under the impedance approach by the following equation:

$\dot{R} = (\dot{Z}_{in}^{(2)} - \dot{Z}_1)/(\dot{Z}_{in}^{(2)} + \dot{Z}_1)$, where $\dot{Z}_1$ is impedance of the atmosphere, and $\dot{Z}_{in}^{(2)}$ is incoming impedance of the layers system at the boundary between upper elementary layer of soil and the atmosphere.

To estimate the influence of surface roughness scattering on the backscattered signal for λ=68cm, the small perturbation method was used.

The value of I_s was calculated as the sum of intensities of each elementary layer ($I_{s,n}$), taking into account the attenuation of $I_{s,n}$ in all upper layers.

Based on these models, the inverse problem of the retrieval of soil moisture content by using scatterometer and radiometers readings was solved.

Calculations using the models showed also that the values of W retrieved from the scatterometer data corresponded typically to their mean values at the top soil layer with the thickness from 5 to 15 cm (depending on *W* and the vertical gradient of *W* at the soil surface). The thickness of the soil layer which forms the natural gamma radiation at the surface depends on its water content. Up to 90% of the total radiation is contributed by the 20-cm layer of dry soil (*W* =5 vol. %), in comparison with 15-cm layer of wet soil (W =25 vol. %). Thus, integration

of the remote sensing into the microwave (P-band) and gamma ranges allows to determine average values of *W* for two different depths within the root-zone.

To consider the impact of the vegetation cover on the backscatter signal the Water Cloud Model (*WCM*) was used. This model corresponds to the first order solution of the radiation transfer through a week medium, where the multiple scattering may be neglected. For the model implementation the value of water content in vegetation per unit area (kg m^{-2}) must be known. This parameter was determined using a normalized differential vegetation index (*NDVI*) acquired from the digital multi-spectral imagery in the visible and near infrared ranges.

According to the calculations based on *WCM*, all crops were practically transparent in the P-band at all stages of development, with the exception of corn and cotton at the maturation stage. At the same time, for the natural gamma radiation all types of cropes were found to be transparent.

Comparison of the soil moisture values retrieved from scatterometer and gamma radiometer data with ground measurements demonstrated a good agreement ($R^2 \geq 0.9$) which indicates high accuracy of both instruments for remote sensing of *W*. Using these methods for soil water content mapping can be useful and supportive for precision agriculture, allowing to determine where and how much irrigation is required. They can also be used as a monitoring system preventing excessive irrigation and water waste.

Fertilizers & Fertility

Theme Heads

Avi Shaviv & Uri Yermiyahu

ON-THE-GO PROXIMAL SOIL SENSING FOR AGRICULTURE

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Information on the variability of different soil attributes within a field is essential to the decision-making process for precision agriculture. On-the-go proximal soil sensing is the most promising strategy to obtain much-needed high-density measurements of key soil properties. Proximal soil sensing systems are based on electrical and electromagnetic, optical and radiometric, mechanical, acoustic, pneumatic, and electrochemical measurement concepts. The major benefit of on-the-go sensing is its ability to quantify the heterogeneity (non-uniformity) of soil within a field and to adjust other data collection and field management strategies accordingly. Integration of different sensing systems in multisensor platforms may allow better prediction of agronomic soil attributes.

FERTILIZATION DECISION MAKING USING GEOMETRIC SEGMENTATION OF MULTISPECTRAL IMAGES

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We propose a new multi/hyper-spectral image segmentation method designed for remote sensing applications. Specifically, we aim our analysis tools to improve fertilization decision making. The core of the application is segmenting multi/hyper-spectral images of agricultural fields into homogeneous zones as a basis for variable rate application.

As a first step toward accomplishing this goal a new state of the art segmentation method of multispectral images was developed. The proposed methodology is based on a multi-scale geometric transformation called the Beamlet Transform and the Beamlet Decorated Recursive Dyadic Partitioning (BD-RDP). The method is applicable for both mono-spectral and multispectral images where each pixel has its corresponding spectral profile vector. The proposed segmentation method is especially effective when the underlying image consist of relatively large segments with smooth boundaries. In this case it performs exceptionally well even when the Signal to Noise Ratio (SNR) is extremely low. The method is unsupervised and assumes no prior knowledge of the image characteristics or features. Furthermore, it involves a single sensitivity parameter which controls the segmentation granularity. Despite of being relatively complex, the proposed segmentation algorithm has a low computational complexity of which is achieved by implicit computations through the Pseudo-Polar Fourier transform (PPFFT). In order to validate the efficiency of the proposed method we used an improved Fuzzy C-mean algorithm as a benchmark for segmentation of multi-spectral images and show that our new method out-performs it.

The proposed method was applied on a sample from an aerial HS image taken over a potato plot under different nitrogen treatments. . The HS image was acquired on 25/5/2007 using a push-broom AISA system in the range of 400-1000 nm, with 210 bands with spectral resolution of 1.3 nm. The multi-scale segmentation successfully uncovered the spatial structures in the image according to differences in N levels

SENSING TECHNOLOGY-BASED PRECISION NITROGEN MANAGEMENT

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Precision nitrogen (N) management (PNM), aiming to match N supply with spatial and temporal variability in crop N requirement, is a promising approach for improving N use efficiency and crop yield, while protecting the environment. For PNM to be successful and practical, remote and direct sensing technologies are crucially important for real-time non-destructive diagnosis of crop N status and estimation of crop N need. The objective of this paper is to review current sensing technologies that can be for PNM, and strategies to apply them to improve N management. Most commonly used sensing technologies include chlorophyll meter based on transmittance, active canopy sensors based on reflectance (GreenSeeker, Crop Circle, Yara N Sensor, and CropSpec), mechanical sensors (like Crop Meter), fluorescence sensors (like Dualex and Multiplex sensors, and MiniVegN sensor) and ultrasonic sensors. They are mainly used as handheld or mounted on tractors or fertilizer applicators. To overcome the influence of factors other than N on sensor readings and accuracy of N status diagnosis, several normalization procedures can be used, including well-fertilized reference plot (strip), no-N reference plot (strip), and relative yield. Several N recommendation algorithms based on sensing technologies will be introduced, and future directions for sensing technology-based PNM will be discussed.

ESTIMATING OLIVE LEAF MINERAL CONCENTRATION USING SPECTRAL REFLECTANCE

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The growing recognition of the health qualities of olive (*Olea eurpaea)* oil has led to an increase in its global consumption. Recent modernization of olive cultivation has introduced and promoted densely planted orchards that are irrigated via systems that can also be utilized for nutrient application. Recent observations have shown that there is an optimal level of nutrients for obtaining maximum yield. Balanced mineral nutrition is being used in order to achieve high quality yield. It is considered economical and environmental necessity. Excessive fertilization has negative plant and environmental effects, such as soil and ground water pollution. Moreover, the rising cost of fertilizers is emphasizing the need for nutrient monitoring in olive trees. Currently, fertilization inspection is based on laboratory chemical analysis of leaf samples. These analyses are expensive and time consuming and therefore are held only annually. This calls for an efficient measurement method to be introduced to the cultivation procedure. Spectral sensing in the visible and near infrared spectrum (400 to 2500 nm) is commonly used for estimation of internal fruit constituents like sugar, oil content and leaf nutrient content in several crops. We studied a method based on spectroscopy in the VIS-NIR spectrum (visible and near-infrared: 400 to 1700nm) for estimating nutrients in olives leaves as a tool for efficient management of fertilization in olive orchards. The optical and spectral setup for measuring leaf spectral reflectance of single leaves and a mix of several leaves are described. Olives Samples (cv. Barnea) were taken from orchard in which fertilization experiment was conducted, allowing a wide range of nutrient levels. Olives were grown in containers filled with perlite substrate at the Gilat Research Center, Israel. The 20 treatments included eight levels of nitrogen ranging from 5 to 202 ppm, seven levels of phosphorus ranging from 0.2 to 20 ppm and seven levels of potassium ranging from 10 to 200 ppm. Spectral reflectance of leaf samples was measured every two months between 2007 and 2010. Reflectance measurements were taken by using two spectrometers: USBHR2000-for VISNIR (450-1000 nm) and LIGA -forNIR-SWIR (1100-1700nm). Nitrogen, phosphorus and potassium concentration of the same samples were measured analytically as reference for calibration and cross validation multi variable regression. Spectral analysis conducted by means of Partial Least Square Regression (PLSR). Nitrogen concentration was found to best be estimated by spectral means, having a global calibration model for the whole season. Potassium and phosphorus models were more local, being more accurate for specific dates. The accuracy and precision of the spectral models are discussed along with the evaluation of their potential to be used as a tool for fertilization management.

DEVELOPMENTS IN PRECISION AGRICULTURE - SENSING THE NITROGEN STATUS IN PLANTS AND IMPLEMENTING INTO FERTILIZING ALGORITHMS

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Nitrogen fertilizer application on heterogeneous sites should be adjusted site-specifically to the needs of the plants thus optimising yield and quality and allowing for economicals savings and decreasing environmental losses.
An overview of the current status in proximal or near-distance sensing the crops´ nitrogen status particularly describing the situation in Westeurope is given. Non-destructive sensing the nitrogen status offers an attractive option to react spatially and temporally to the varying needs of plants.
A number of solved and unresolved issues are addressed such as: How well do sensors reflect the nitrogen status, which nitrogen parameters should be detected, what do sensors see, for which crops algorithms have been developed, do we have to consider cultivar-specific effects, how to account for the nitrogen supply from soil, should other parameters than the plants´ nitrogen status such as the water status of plants or the soil water status be considered as well? Is there a way to absolute information?
A number of sensors are compared in their efficiency to detect the nitrogen status and their performance as affected by changing ambient conditions is briefly outlined.
Existing algorithms to implement the sensed information into fertilizer application are described and needs for further improvements are outlined.
Non-destructive sensing allows to implement information to site-specific nitrogen application, but usage of such information to site-specific dressing of growth regulators or fungicides is becoming increasingly adopted by farmers making it even more attractive. More recent developments to improve the phenotyping process in plot experimentation, particularly also in breeding applications, will add to the overall adoption and result in further improvements.

SOIL FERTILITY AND FERTILIZERS – WHAT ELSE SHOULD WE SENSE?

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Spatial and temporal in-field sensing is much easier adaptable to plants than to soil properties. Frequently plants are used as indicators of soil fertility. However, a strong need exists to sense the soil to further improve the nitrogen management. Most of the nitrogen is applied either as pre-season or early season dressings where plant information is not available or differences in plant growth are too subtle. Plant available nitrogen should be available as pre- or early-season information. To bridge this gap a simplified on-farm procedure that allows quickly obtaining this information has been further elaborated and made universally available via the Web (http://www.nitratesoiltest.com). Still a long way is to even quicker assessments of soil nitrate.

Even with best management practices that are tightly linked to demand oriented fertilizer applications and to the expected yield, nitrogen use efficiency will only be moderate at best, or with less good practices still prevailing continue to remain unsatisfactorily low. This points to a need to better sense the leaks and losses in our nitrogen management practices. Of prime concern are leaching losses of nitrate to the groundwater and surface water and emissions as ammonia and nitrous oxide to the atmosphere. Even though ammonia losses do primarily derive from organic fertilizers, ammoniacal mineral nitrogen fertilizers can substantially contribute as well. Most important are losses from urea that represents the dominant fertilizer form worldwide. The range of ammonia losses reported in literature varies from little to up to 60%. In West-Europe emission factors of 23% to 11.5% for grassland or arable crops are currently adopted. In contrast we found markedly lower emissions, which point to a need to further evaluating such losses. Ammonia losses can substantially be decreased by newly developed urease inhibitors.

A similar notion applies to nitrous oxide losses that most effectively can be reduced by about 40% by nitrification inhibitors, with some newly developed NI´s being particularly effective. Whereas generally about 1% of the applied nitrogen fertilizer is assumed to be lost as nitrous oxide, other reports suggest that this number might be rather at 3%. Seen the huge impact of nitrous oxide and the important role of agriculture contributing to global warming, a better assessment of the potential losses are urgently required.

Misuse of organic fertilizers is seen as the main obstacle to further improve nitrogen management. In West-Europe between 30-60% of the nitrogen input may be in the form of organic fertilizers. Whereas the composition of mineral fertilizers is well-known, this is not at all the case for organic fertilizers such as animal derived manure or slurry. A better appraisal of the nutrient composition of organic fertilizers would substantially contribute to improvements in nitrogen management and to decreased emissions. Off-line or on-line sensing of nutrients in slurry storage tanks or slurry tankers could greatly contribute along these lines. Some recent developments are illustrated.

IN-SITU TRACING OF N TRANSFORMATION IN SOIL AND GAS PHASES USING ISOTOPES AND FTIR SPECTROSCOPY

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Nitrogen derived from agro-ecosystems poses severe threats to the environment via nitrate leaching and emission of N_2O that contributes to global warming. Knowledge regarding the pathways involved in N_2O production is still limited despite efforts to quantify mechanisms and sources of such emissions. Even the attainment of Gross Rates of well known processes such as N-mineralization or nitrification is still very limited and dependent on sophisticated, expensive and destructive methods. A better understanding of the sources and quantification of Gross Rates are essential for developing better management tools and mitigation measures.

Promising techniques for investigating N transformations and N_2O production from soils include dual-isotope labelling and monitoring of isotopologues/isotopomers in the gas phase. These however, need the utilization of Isotope Ratio Mass-Spectrometry (IRMS) for quantitative investigation and laborious pre-treatment of samples before measurements. Fourier Transform Infrared Spectroscopy (FTIR) with the ability to monitor changes in N-gases (using long-path gas cells) and in the soil phase (using ATR, Attenuated Total Reflectance) while using smart labelling of $^{15}N/^{14}N$ and/or $^{18}O/^{16}O$ mineral-N species provide powerful tools for direct or *in-situ* investigation of N-dynamics in gas-liquid-soil phases.

Efforts for developing a novel integrative method based on FTIR spectroscopy for continuous monitoring of isotopic N-species directly in moist soil and gas phase are presented and discussed emphasizing their importance to serve as efficient tools to better understand and quantify N-dynamics in complex systems. The work consists of several stages: Development of methods for direct determination of concentrations of mineral-N isotopic species in wet soils using FTIR-ATR systems; Modification of methods for determining concentrations of N-isotopic or isotopomeric species of N_2O in long-path (LP) mid-IR gas cells; Development of combined LP-ATR-FTIR chambers allowing continuous investigation of changes of mineral N-species in soil (FTIR-ATR) and N-gases (LP-IR) under various environmental conditions.

Development of the combined LP-ATR-FTIR chambers should also serve as a means for up-scaling to field measurement techniques.

THE EFFECT OF WAVELENGTH AND MATHEMATICAL FORMULA ON THE RESULT OF MEASUREMENT WITH DIFFERENT VEGETATION INDICES

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Not only to avoid over-fertilization and to reduce the environmental burden but also for economic reasons, precision farming becomes more and more important. By using reflectance measurements of the canopy and adjacent mathematical analysis certain crop parameters like N (nitrogen) content, N-uptake and plant biomass above ground are appreciable.
Over a four-year period, from 2007 to 2010, two different plot trials in summer wheat were conducted. The first trial consisted of two different cultivars of summer wheat (cultivars Taifun and Triso) and four N-rates (0, 100, 160 and 220 kg N ha^{-1}). The second trial consisted of only one cultivar (Taifun) with seven N-rates from 0 to 220 kg N ha^{-1}). Each trial was conducted as a double plot trial with four replications. One plot was for non-conducting sensor measurements and harvesting with the plot combine, whilst the other plot was for biomass sampling during the vegetation period. Biomass samples for nitrogen analysis as well as sensor measurements were conducted four times during the vegetation period.
Reflectance measurements have already proved their ability to guide nitrogen fertilization by detecting the N-uptake of the canopy. This fact could also be observed in this study where the N-uptake of different growth stages of summer wheat was well represented, especially with vegetation indices using wavelengths more in the infrared region. For example the linear regression analysis of the NDVI with its typical wavelengths of 670 nm and 780 nm, the coefficient of determination were R^2 = 0.71 in the growth stage EC 30, R^2 = 0.47 in EC 37, R^2 = 0.64 in EC 49 and R^2 = 0.60 in EC 65, with all results significant at p = 0.000. Aside from the results of the regression analysis, the ANOVA of the NDVI showed a typical saturation effect. That means that it could only differentiate the cultivars with low N-content from these with higher N-content. Aside of the NDVI, other vegetation indices showed better results. The results of the linear regression analysis of the simple ratio (SR), just a quotient of two different wavelengths with 740 nm and 780 nm, were considerably better. The R^2-values were R^2 = 0.92 in EC 30, R^2 = 0.75 in EC 37, R^2 = 0.87 in EC 49 and R^2 = 0.88 in EC 65. In contrast to the NDVI the saturation effect almost disappeared and this ratio showed the ability to differentiate the various N-levels. With the vegetation index Yara-ALS it was somewhat different. Although the R^2-values were high at the various growth stages, from R^2 = 0.89 in EC 30 to R^2 = 0.84 in EC 65, the ANOVA did not show the same good results in the differentiation of the N-levels. In this context, the study's question was to analyse what are the main impact factors for the suitability of the vegetation indices. Is it more the mathematical formula or is it the wavelength utilized in a vegetation index. To analyse this topic the mathematical formulae of the vegetation indices were modified to calculate the indices with different wavelength combinations from 670 nm up to 850 nm, with steps of five nm. Thereby the results of the statistical analysis for the vegetation indices changed considerably. NDVI with a wavelength combination of 740 nm and 780 nm as well as 740 nm and 810 nm did not show the saturation effect anymore. The R^2-

values increased to R^2 = 0.92 in EC 30, R^2 = 0.74 in EC 37, R^2 = 0.88 in EC 49 and R^2 = 0.87. The same effect was observed with the other vegetation indices. At a wavelength combination of 740 nm and 780 nm as well as 740 nm and 810 nm, each index reached the maximum in the coefficient of determination together with the ability to differentiate the various N-levels well. With these combinations of wavelengths the results of the indices were on the same level, regardless their mathematical formulae. The results show that the mathematical formula is not very important; the main impact factor on the results is the right combination of the wavelengths, which are presented in this study.

USING OPTICAL SENSORS TO SCHEDULE VARIABLE RATE APPLICATION OF AGROCHEMICALS ON COTTON

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The paper reports on a 3-year project designed to evaluate the feasibility of using the GreenSeeker® RT200 mapping system to drive variable rate application (VRA) of plant growth regulators (PGRs), defoliants, and nitrogen on cotton in Georgia, USA. The results indicate that NDVI appears to be very good tool for differentiating management zones early and late in the growing season. At mid-season, when the entire field is covered by a solid green canopy, NDVI values become saturated and is not useful for creating management zones. This paper will present the results or our work. Results will include costs and benefits of using VRA on cotton.

Rangelands

Theme Heads

Tal Svoray & Avi Perevolotsky

LIDAR AND BALLOON AERIAL PHOTOGRAPHY FOR FINE SCALE STUDIES OF VEGETATION DYNAMICS

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In Mediterranean regions, the combination of disturbances, life histories, plant regeneration traits, and micro-habitat variability form highly heterogeneous vegetation mosaics which shift in space and time. Consequently, structural-based forest classification is emerging as a better alternative to the traditional botanically-based, community oriented classifications for studying vegetation dynamics as well as for planning and management. Here, we develop two methodologies, based on two remote sensing techniques, in order to enhance our understanding of Mediterranean vegetation dynamics. First, we present an approach for mapping vegetation units based on segmentation of height and cover information derived from LiDAR imagery. We assessed its feasibility and accuracy in Ramat Hanadiv Nature Park.

On a separate project, we used balloon aerial photography to map and analyse vegetation structure at a very high spatial resolution (pixel size < 0.04 m), looking for structural differences among plots subjected to different disturbance/management schemes (grazing, shrub clearing, and undisturbed control). We used landscape metrics, commonly used to quantify coarse-scale spatial patterns of landscapes, to characterize fine-scale vegetation structure. Six of the seven metrics we evaluated revealed significant differences between treatments and control. We conclude that landscape metrics are useful for quantifying the very fine scale impact of disturbance on woody vegetation – given that data at very high spatial resolution are available.

CORRELATING GPS MOVEMENT METRICS WITH ANIMAL BEHAVIOUR

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The continuous recording of animal activity will enhance our understanding of animal behaviour and landscape utilisation by grazing livestock. Traditionally, collection of animal behaviour data relied on manual observations which are time consuming, expensive and may be unrepresentative of the full range of behaviours. Recent advances in animal tracking technology have meant that position loggers have become more readily available. GPS or local, radio frequency-based position loggers offer great potential for improving the management of grazing livestock, however position loggers generate a large amount of data. The question then is how do livestock managers use this information to make better decisions?

With support from the Cooperative Research Centre for Spatial Information (CRCSI), the Precision Agriculture Research Group at University of New England (UNE-PARG) are investigating the use of GPS-based position loggers on grazing sheep and cattle to answer this question. The main aim is to correlate movement metrics eg velocity, distance travelled with the animals' physical environment and observed behaviour. We will then use the best metric of behaviours in models and decision support tools (DST) to help livestock managers improve feeding management decisions in variable climates.

We have tested Bayesian change point analysis of velocity to identify a change in behaviour because of lambing in pregnant grazing Merino ewes (Taylor et al. 2010). This analysis revealed a high correlation (r=0.89) between a change in average velocity and lambing occurring, suggesting that this method could be useful in identifying lambing behaviour. However, average velocities between 0500 and 100h were shown to be the most consistent, therefore potentially limiting its effectiveness. More research is required to determine whether other metrics in combination with a change in velocity may enhance this methods' effectiveness. Another metric being tested is 'home range' using minimum convex polygon and kernel distribution analysis on the same sheep data. Initial results indicate that lambing behaviour reduces the home range size significantly compared to that of ewes 7d before and 7d after lambing (Dobos unpublished).

Biomass availability and quality can limit intake by grazing animals and also affect grazing behaviour. There is a distinct diurnal pattern of grazing behaviour in ruminants and this is being used to test whether behavioural changes can be identified using position data when biomass availability and quality are modified because of grazing. The metrics being tested include velocity, distance travelled, 'home range' and movement trajectories.

From this research we hope to determine a suitable metric identifying a change in behaviour from the GPS data. Once determined, the metric(s) will be then incorporated into DST to help livestock managers improve feeding management and landscape utilisation of grazing sheep and cattle.

MONITORING EFFECTS OF CONROLLED GOAT GRAZING ON THE LANDSCAPE: DIFFERENT APPROACHES AND DILEMMAS

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Ramat Hanadiv is a 500-hectare park in southern Mt. Carmel, Israel, in which the dominant vegetation formation is Mediterranean garrigue of heterogeneous density and structure. Water regime, soil formation and land use history account for much of the heterogeneity in vegetation density and developmental stage. The land had been subjected to traditional grazing systems for thousands of years but livestock were excluded when the park was established in the early 1950's, resulting in a continuous increase in shrub cover. Due to fire hazard, and in order to manage the landscape to increase amenity value and biodiversity, several management strategies were developed to control shrub encroachment. A key factor was the introduction of livestock grazing, including a herd of beef cattle that graze most of the park during 3-5 months and maintaining fuel breaks. Since 2004, targeted grazing by a herd of 140 goats was added. The goat herd grazes at certain GIS-defined polygons of various sizes (1-20 hectares), covering one tenth of the park area.

As part of the adaptive management approach applied in the park, the introduction of goats was accompanied by a monitoring program for assessing the impact of grazing on various landscape parameters and the extent to which management objectives have been accomplished. The impact of goats on the landscape is being assessed by comparing grazed and ungrazed areas, over time.

Since our study serves as a management supporting tool more than a structured research design, and due to cost/benefit considerations, we started with a more extensive and qualitative approach, focused mainly on landscape visual features and human use values. Visual estimations of vegetation cover, height, landscape accessibility and transparency were conducted, as well as an effort to interpret a set of 'still' photos taken from fixed points before and after the grazing.

With time, we have found those methods to be unsatisfactory and hard for interpretation, and the necessity arose to find more practical parameters.

A new long term protocol for evaluating the effects of controlled goat grazing on different landscape components was gradually developed and applied from 2010. It includes several monitoring paths:

Drawing detailed "structural profiles", based upon a set of fixed transects, from which the dimensions and distribution of gaps between individual woody plants are calculated.

Quantitative analysis of changes in the cover, height and species composition of the woody component and categorical estimations of crown density, defoliation and debarking levels.

Aerial photography interpretation, to evaluate temporal changes in woody cover and common landscape pattern measures.

Analysis of the effects of goat grazing on ecosystem functioning, expressed by nutrient cycling and litter decomposition (grazed vs. ungrazed plots)
Grazing intensity and efficiency were monitored directly, by combining logs of every grazing bout with telemetry data and indirectly, by applying fecal NIRS methodology to evaluate the nutritional value of the goats' diet.
Monitoring goat effects to support management sometimes creates a tension between the need of long term quantitative data and our inability to stand up to the complexity and resources needed for a profound research. Dilemmas are present regarding the cost effectiveness of different methods and the right frequency of monitoring such processes. We suggest building “adaptive protocols” that combine different techniques and, with time, let “natural selection” choose the most useful parameters and methods.

THE USE OF GPS FOR STUDYING CATTLE DISTRIBUTION IN MEDITERRANEAN RANGELANDS

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There is little information on the circadian grazing behavior and site selection of free-ranging animals, especially in Mediterranean rangelands. Objective information on the interrelationships between landscape and animals can help plan the management of such systems more rationally. Previous studies on the spatial distribution, habitat selection and site preference of cattle in rangelands show that in many foraging environments cattle do not exploit the available area uniformly. Grazing distribution patterns are affected by abiotic factors such as slope, distance from water, shade and wind and by biotic factors such as vegetation composition, quantity (biomass) and quality.

The aim of this presentation is to demonstrate the use of the Geographic Position System (GPS) to study the foraging behaviour of cattle grazing hilly Mediterranean grasslands and woodlands. In addition, we would like to show the ability of this technology to assess the effect of external resources such as water sources, feeding sites and shade on cattle distribution pattern. This presentation is based on results from studies conducted on different farms in Northern Israel, where GPS units were fitted on free-ranging cows in order to examine their grazing behaviour in heterogeneous landscapes (terrain and vegetation types).

The different studies reviewed hereby were conducted at Karei Deshe and HATAL experimental Farms, located in the Eastern and Western Galilee, respectively and on five other private farms in the Golan Heights. The distribution and activity of the cattle were monitored using Lotek GPS collars (2200 and 3300 series). GPS tracking systems enabled us to study the use of the range by the cattle along the whole day in a reliable and accurate way in 5-min intervals. In all of the studies the vegetation of the experimental paddocks was sampled to measure the standing biomass in order to determine the condition of the pasture. Spatial information was processed with the ArcView 9.x software of the Geographic Information System (GIS). The basic GIS layers of the project included an aerial photograph of the study area, a topographic map, fence lines of the paddocks, a subdivision of the paddocks into terrain types or vegetation types, the locations of water and feed sources and location fixes of the cows during each period of the study.

It was shown that in a complex Mediterranean rangeland dominated by herbaceous vegetation, during the green season, while the standing biomass is high, cows significantly preferred to graze the more level terrains. However, as the biomass became depleted, the exploitation of the pasture into the dry season became increasingly homogeneous. In this type of rangeland, but during the hot and dry season, placement of external water troughs, feeding sites and shade had a highly significant effect on cattle distribution. These specific results indicate the potential of selecting the locations of external resources to manipulate cattle movement and to

improve rangeland management. Thus it might be possible to change grazing patterns and improve forage utilization by altering resource positioning. In woodland vegetation formation the cattle's spatial distribution was found to be related to the different vegetation types. During the winter and spring cattle grazed in the open brush areas which were rich in herbaceous species. But during summer, when the herbaceous vegetation was dry, cattle spent relatively more time in areas dominated by a dense cover of trees – a source of forage and shade.
The applied methodologies of GPS, mounted on cows, combined with the ArcView 9.0 software (GIS), provide a reliable tool for monitoring cattle behaviour and distribution. They can even be used in dense woodlands, where animals can hardly be sighted/observed while grazing. We conclude that improved utilization of a hilly range can be enhanced by applying information obtained by these advanced technologies.

EVALUATING THE EFFECTS OF DIFFERENT SOIL MANAGEMENT ON PRODUCTIVITY IN ARID ZONES USING MODIS DATA

Mor Mussery A.[1], Stefan Leu[1,2], Lensky I. M.[3]
1- Judea Research and Development Center
2-Jacob Blaustein Institute for Desert Research
3- Bar Ilan University, Faculty of Geography and Environmental Sciences

The North-Eastern part of the Negev (receiving around 200 mm precipitation per year), similar to wide parts of the world is suffering from significant degradation due to unsuitable soil management, such as heavy grazing, tilling and soil movement for forestation (Contour Trenching). Theses processes are gradual, long lasting and affected by multiple factors that make it hard to model and predict the results, a process essential for coping with them successfully. As a case study we chose an area located in Arad valley North of Beer Sheva and South of Yattir forest, near Hura and Meitar. The area contains different soil management histories. We defined: Tilled (Tilled at 2007 for wheat), Abandoned (Tilled last at 2004 and abandoned), Heavily Grazed (Open area with uncontrolled grazing) and Conserved, inside a family farm established in the early 1990 where grazing was reduced and restricted. In a project conducted by the Judea R&D team from 2008 till 2010 we examined manually the productivity by sampling the on-soil biomass and soil quality, and compared the results to the NDVI data from MODIS for the years 2000 till 2010. The MODIS satellite (NASA) begun its analysis in 1999 with intervals of 16 days with a range of different wave lengths and a pixel resolution of 250*250m.

We found that consistently the maximal NDVI (Normalized Difference Vegetation Index) differences between spring and summer are at the Conserved Shrubland as compared to those affected by human interference (Heavily Grazed, Tilled, Contour Trenched and Abandoned) with around three fold difference. These differences are dependent in the precipitation amount. Close inspection revealed the low rehabilitation rate in time (as compare to the open area - the heavily grazed) and after the last tilling of the abandoned area only after four years we observed small rehabilitation.

The same characteristics and differences between the treatments were found by manually sampling (the large standard error we got in this method can indicate about one of the advantages of using MODIS data, that as opposed, gives one representative value. As a second step we graphed all the data (each 16 days) from 2003 till 2005 (with high precipitation) and averaged them by Fourier analysis. We noticed later appearance of the high NDVI values (late flora growth) in the human interference treatments as compared to the Conserved Shrubland where the increase begun already two weeks after the first rain events. This early flora appearance is crucial for stabilizing the soil and preventing runoff and erosion later. Similar results were found also in infiltration and Field capacity measurements that were done. The main shortcoming of the MODIS is his large pixel. One of the interesting treatments in the area is the ***Acacia victoria*** woodland cannot be resolved by MODIS due to its small dimension

(150*70m). To overcome this problem and estimate the NDVI changes, we combined other satellites with smaller pixel readings (such as LANDSAT-15*15m).

In summary, based on our results the advantages of using MODIS data in environmental research are (except from that are represent all other satellites readings):

a. The pixel dimensions (250*250m) can indicate the real biomass value mainly in heterogenic areas (natural, shrublands areas), as compared to the higher versatility achieved by sampling manually.

b. The 16 days intervals can present inter seasonal vegetation changes (if they exist).

c. The continuous data can be helpful for predicting long term processes, while most field research is limited to 3 year intervals. Using the MODIS data in combination with manual methods can give new insight to the understanding of the long term ecological and environmental processes occurring in arid environments.

REMOTE SENSING OF SHRUBLANDS' PATTERNS AND THEIR RELATIONSHIPS WITH BIOMASS ALONG SEMI-ARID CLIMATIC GRADIENT

Lev Karnibad, Maxim Shoshany
Faculty of Civil and Environmental Engineering
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In Mediterranean ecosystems, shrubland vegetation is influenced by fragmentation and aggregation processes that are regulated by water availability and human disturbance. These processes are responsible for patch pattern formation of the vegetation and soil in Mediterranean shrublands. We hypothesize that shrublands biomass distribution can be mapped based on a combination of patch pattern properties and environmental information such as precipitation rates. However, at meso-scale of LandsatTM imagery, each pixel is represented with a mixture of reflectances from several different surface cover types. Shrubs and soil cover proportions can be estimated by means of spectral Unmixing. We propose that patch pattern properties can be then expressed by image texture properties of the vegetation and soil fractions. If so, image texture properties may be indicative of the regional shrublands biomass. This approach will be tested along the climatic gradients of the Judean Desert and of the Northern Negev.

ASSESSING AND MAPPING GRAZING GRADIENTS AROUND WATERING POINTS IN CENTRAL ASIAN DESERTS USING SATELLITE IMAGE PROCESSING AND GEOSTATISTICAL METHODS

Arnon Karnieli, Tal Svoray, and Uri Gilad
Ben Gurion University of the Negev

Soil and vegetation degradation around watering points has been observed in many drylands around the world. It can be recognized in spaceborne imagery as radial brightness belts fading as a function of distance from the water wells. The primary goal of the study was to characterize spatial and temporal land degradation/rehabilitation in the Central Asian drylands. Tasseled Cap's brightness index was found to be the best spectral transformation for enhancing the contrast between the bright-degraded areas close to the wells and the darker surrounding areas far from and in-between these wells. Semi-variograms were derived to understand the spatial structure present in the spaceborne imagery of two desert sites and in three key time periods (mid-late 1970s, around 1990, and 2000). A geostatistical model, namely the kriging interpolation technique, was applied for smoothing brightness index values extracted from 30 to 80m spatial resolution images in order to assess spatial and temporal land-cover patterns. Change detection analysis, based on the kriging prediction maps, was performed to assess the direction and intensity of changes between the study periods. These findings were linked to the socio-economic situation before and after the collapse of the Soviet Union that influenced the grazing pressure and hence the land-use/land-cover state of the study sites. The study found that degradation occurred in some areas due to recent exploration and exploitation of the gas and oil reserves in the region. Another area was subject to rehabilitation of the rangeland due to a dramatic decrease in the number of livestock due to socio-economical changes after the independence of Kazakhstan in 1991.

REMOTE SENSING OF RANGELANDS – MATCHING CAPABILITIES WITH THE NEED FOR INFORMATION IN A CHANGING WORLD

Stuart Marsh
School of Natural Resources and the Environment and Graduate Interdisciplinary Program in Arid Lands Resource Sciences, University of Arizona, Tucson, AZ, USA

Rangelands comprise 46 percent of the Earth's land surface and in the U.S. over 50 percent of our western states are rangelands. Though often visualized as an ecosystem of lesser concern in the context of global change, their extensive expanse coupled with their providing over 70% of the forage for domestic livestock production makes it critically important that we improve our understanding of rangeland conditions across the globe. The ecosystem goods and services they provide include biological diversity, environmental protection, forage and crop production, recreation, poverty alleviation, water and carbon sequestration. Unfortunately, our understanding of these systems and how they will react under a changing climate is insufficient to meet the challenges we face. Recent estimates of the percent of the world's rangelands that are degraded vary from 20 percent to nearly 75 percent. This degradation has generally been caused by overgrazing, invasive species, and exurbanization, yet we have little understanding of the relationship of these drivers to changing precipitation and temperature regimes at either the regional or global scale. Not only are we lacking an understanding of baseline conditions of biomass, net primary production, species and plant functional type distributions, and forage but we have little insight into more complex questions regarding climate change: 1) Will woody plant encroachment increase or decrease above and/or below ground carbon sequestration? 2) How will non-native plant invasion adversely affect grazing and other ecosystem services? 3) Will changes in grazing practices affect carbon and nitrogen stocks and what could be the impact of brush management on carbon sequestration?

Given the importance of these questions to our understanding of the impacts of global climate change on rangelands and the potential role of rangelands in reducing greenhouse gasses, we must utilize a combination of field and remote sensing tools to achieve a more comprehensive perspective of rangeland conditions. Important variables that satellite and airborne remote sensing can help to map and monitor include albedo, annual net primary production (herbaceous and woody biomass), surface temperature and soil moisture, phenology, and forage. This talk will explore the current state of remote sensing of rangelands, what questions these tools can help to answer about rangeland ecosystem services, and what opportunities lay ahead in the integration of multispectral and multitemporal data with new remote sensing technologies including Lidar, observations using unmanned aerial vehicles, and the use of continuous long-term data sets. These measures can then be coupled with field data from existing and new ground observing systems at multiple scales to increase our understanding of rangelands.

AUTOMATIC RECOGNITION OF JAW MOVEMENTS OF GRAZING ANIMALS USING AN ACOUSTIC SENSOR

NAVON Shilo[1], MIZRACH Amos[2], HETZRONI Amots[2], UNGAR Eugene David[1]
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Improved understanding of herbivore feeding behaviour in relation to the environment, and especially to the vegetation, is essential for efficient and sustainable management of the world's rangelands. The most basic element of feeding behaviour is the jaw movement, and grazing can be defined in terms of the sequence of bite and chew jaw movements over time. Despite decades of research, the feeding behaviour of herbivores in the field has not yet been well quantified, and this is largely due to methodological constraints. A promising method for monitoring grazing behaviour is by acoustics, whereby a microphone is pressed against the skull of the grazing animal. With the head acting as a soundbox, a well-trained listener can identify and classify jaw movements readily. However, because sequencing has been performed manually, application of the method has been restricted to grazing experiments of very short duration. In order to exploit the full potential of the method, the development of signal processing algorithms for identification and classification of jaw movements is required. Our goal was to develop an algorithm for automatic recognition of jaw movements in a grazing session with a minimum of *a priori* parameters and thresholds. The algorithm would need to cope with the enormous variability presented by real-life situations in terms of species of animal (cattle, sheep, goats), foraging environment (grassland, shrubland, woodland), and vegetation state (green versus dry), as well as variable and unpredictable background noises. For the development and calibration of the algorithm, we recorded approximately 30 grazing sessions of goats of 30-min to 4-h duration, in different foraging environments. For cattle, we used recordings of grazing sessions conducted in the UK.

The algorithm operates in the time domain only and is therefore based on amplitude values. We looked for measurable properties which are unique to the jaw movement sounds, in relation to the background noise, and that are valid for most of the animal–environment combinations. Since the sound intensities of both jaw movements and background noises are variable, these properties could not be expressed in terms of absolute numbers. We assumed that: 1) the start of a jaw movement is accompanied by a sharp change in sound intensity; 2) in the absence of noise, jaw movements produce the most intense sounds in the recording; 3) a jaw movement is usually part of a sequence; 4) a jaw movement has a limited duration. This last property is defined in absolute terms, but is valid for all jaw movements within an animal species, because it is based on highly conservative anatomical-behavioural features. Note that items 1 and 2 deal in relative rather than absolute terms. The algorithm reduces the large stream of amplitude values that describe the sound intensity, into a subset of values that capture the shape of the amplitudinal envelope. Starting from the first of these values, the

algorithm computes a form of running average. A new sub-section is marked when the average amplitude of the values contained in the upcoming upstream sequence deviates markedly (up or down) from the running average of downstream values. The process then repeats itself starting from the beginning of the new sub-section. This iterative process subdivides the sound file into sections whose sound characteristics differ from those of its neighbours. These subsections are then analysed in order to classify them as "quiet" sections and "active" sections (background noise or jaw movement). This process is recursive and is not based on absolute thresholds but utilizes patterns of "quiet" and "action" as well as their duration. Active sections whose duration is within a certain range are assumed to be jaw movements, and the rest are assumed to be background noise. Finally, the algorithm examines all jaw movements that have a large contrast between their own sound intensity and that of their immediate background, and uses this information to derive statistics to filter out candidate jaw movements of relatively low contrast which are probably background noise. Thus far, the algorithm has been tested on two cattle grazing sessions and achieved 95% correct identification of jaw movement events.

THE ROLE OF PLANTS AS ECOSYSTEM ENGINEERS IN RESILIENCE TO CLIMATE CHANGE

Moshe Shachak
Ben Gurion University

In drylands landscape structure is controlled by two ecosystem engineers, soil microphytes and shrubs. Soil microphytes adhere to the soil particles by secreting polysaccharides, thus forming biogenic soil crusts. Shrubs engineer the environment above and below ground. Above ground they can form soil mounds and below ground modulate the soil properties by their roots. The two engineering modes create shrub patches in the landscape.

The two phase mosaic formed by the engineers creates a source-sink system where the crust is a source of soil, water, organic matter and nutrients while the shrub patch is the sink.

Most of the productivity and diversity of the system is concentrated in the sink patches. Climate change such as the increase in frequency and severity of droughts may affect the function of the two phase mosaic by causing shrub dieback. This can transform a shrub land into crust land by increasing leakage of resources and decreasing productivity and diversity (desertification).

Based on our long term research at LTER sites in the Northern Negev, Israel, we present two models depicting how climate change can cause state changes from shrub land to crust land and how the mode of shrub engineering can prevent this transition. Our main proposition is that the resilience of a two phase mosaic to drought depends on whether the engineering is by mound formation or by subsurface soil modulation.

When the engineering mode is mound formation, shrubs dying due to drought expose the underlying mound to erosion by rainfall and runoff. The eroded patch is then colonized by microphytes which form soil crusts. This process takes between five to ten years. To rebuild the soil mound by a shrub takes hundreds of years. Therefore, once the soil mound is eroded the area will then be transformed from shrub land to crust land and the recovery time is long. When the engineering is through the roots the system is more resilient to drought. Even if the canopy dies back the shrub patch continues to function as a sink because the roots function as tubes that channel the water to deeper soil. The patch continues to function as a shrub patch even though the shrub has been decimated. The enriched patch prevents crust encroachment and stimulates regrowth of the shrub. In this case there isn't a transformation from shrub land to crust land and the recovery rate is rapid.

Based on the two case studies we present a general model on state changes in shrub lands due to climate change. We demonstrate that a main factor in gauging state transition due to climate change is the mode by which plants engineer their environment.

SHRUBLANDS' BIOMASS – PATTERN RELATIONSHIPS ACROSS CLIMATIC GRADIENTS: MODELING AND IMPLEMENTATION USING REMOTE SENSING DATA

Maxim Shoshany
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Shrub biomass is an important food component in semi-arid rangelands. Rainfall amount is a primary determinant of shrubs growth potential. Integrating data from wide range of semi-arid sites allowed formalization of Biomass-Precipitation Model describing the exponential growth of biomass with increasing rainfall. The balance between rainfall and water losses on one hand and grazing intensities on the other hand regulate the actual size of shrubs and their density. In this research it is further hypothesized that the pattern of shrub patches highly influence their productivity. Two new models which link patch pattern properties and the Water Use Efficiency were developed. In the first model, Patch pattern properties were parameterized by the Edge Ratio (ER), the ratio between the area of isolated small plants together with those at the boundary of larger vegetation patches to the total vegetation area. High edge-ratios are indicative of low WUE and therefore low biomass productivity. In the second model the patch pattern based WUE (PP_{WUE}) is directly proportional to the vegetation (shrub) coverage and inversely proportional to its fragmentation while the weight of this fragmentation is modulated by the soil coverage. Multiplying the Mean Annual Precipitation (MAP) by these two new Water Use Efficiency parameterizations in the existing Biomass-Precipitation model may facilitate estimation of expected productivity across the semi-arid to arid climatic zones.
Implementation of the two new models with remote sensing data required accounting for scaling effects. The assumption of self-similarity and the close affinity between the Edge Ratio and the Fractal Dimension allowed for the calculation of the WUE with the Fractal dimension. The second PPwue Model was utilized based on a new Image Parameterization of the distribution of shrub cover fractions. During the conference we will present the new two image based pattern parameterizations together with their implementation for the estimation of shrublands biomass along the climatic gradient of the Judean Mountains in Central Israel.

SPACE-TIME DYNAMICES IN PP OF ANNUALS: MODELING WITH GEOINFORMATICS

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We used data from extensive field research and a recently published spatio-temporally explicit model to study factors affecting long-term variation in herbaceous vegetation production in two dry ecosystems: semiarid and Mediterranean. The model was executed along 30 years (1979-2008) at the semiarid site and along 21 years (1986-1990; 1993-2008) at the Mediterranean site. The results show that between-season variation in ecosystem productivity was highly correlated with soil water storage and less with rainfall patterns. Therefore, improved soil water storage compensated for poor rainfall resources along the growing season. Water-improved areas are affected by unsteady environmental conditions that differ between years. However, in areas of poor soil water storage, production processes become more vulnerable to drought periods and these areas are more dependent on rainfall characteristics and on effective rainfall events. Application of the model to climate change scenarios show: a) A reduction by 5-35% in annual rainfall did not affect productivity in the Mediterranean site, but a 25-35% decrease in rainfall changed spatial patterns of productivity in the semiarid site. b) Similar results were observed when temperature and evaporation rate were increased; when the magnitude of rainfall events increased while their frequency were decreased; and during a long mid-season dry spell. c) In both ecosystems, changes in the temporal distribution of rainfall, especially at the beginning of the season, caused the largest reduction in productivity, which were followed by changes in productivity patterns in space. d) Long-term data gathered during the last three decades indicated that both environments exhibited high resilience under highly fluctuating weather conditions. These results imply that the response of dry ecosystem to climate change scenarios is mainly characterized by structural changes. Moreover, these ecosystems are more resilient than expected and their herbaceous component might undergo drastic changes only under more severe scenarios than those currently predicted in the literature.

HOW WELL CAN WE INFER THE ACTIVITY TIMELINE OF ANIMALS ON RANGELAND?

UNGAR, Eugene David
Department of Agronomy and Natural Resources, Institute of Plant Sciences, Agricultural Research Organization – Volcani Center, Bet Dagan, Israel

The activity timeline of a grazing animal is of interest for a variety of reasons. First, knowledge of how an animal divides its time among active grazing, resting, and pure travel can help explain the results of empirical studies that measure animal output responses to changes in grazing management controls. Second, in conjunction with geolocation, the activity timeline enables us to refine our understanding of how animals interact with the landscape. Third, to the extent that behaviour responds systematically to changing sward conditions, the activity timeline could serve as an indicator to fine-tune grazing management decisions in real time. Fourth, if sensor costs are sufficiently low, it may be feasible to deploy on all animals and improve management decisions related to selection, breeding, and early-detection of illness. Activity needs to be inferred from information provided by some kind of sensor placed on the animal. Inference is a statistical process that is unlikely to yield perfect results. It is also totally dependent on the gathering of calibration data, which can be both difficult and expensive. Three technologies will be discussed that can enable the activity timeline to be inferred: sensors based on GPS, pedometry, and acoustics. Quite a few commercial companies produce GPS devices for deployment on domesticated ruminants. These are designed to withstand extreme conditions of use and to provide great flexibility in operational schedule. They need to store large quantities of data until the device is retrieved, or transmit data wirelessly. Modern devices transmit data over cellular phone networks. The primary trade-off in the use of such devices is between GPS fix interval and battery life. In principle, activity can be inferred from inter-point distance: short, intermediate and long distances correspond to rest, graze and travel activities, respectively. But the accuracy of classification depends on the GPS fix interval and the level of GPS error. The main problem tends to be confusion of rest and graze. Lotek GPS collars incorporate motion sensors, and data from these can be used to improve classification. We are currently testing a small but powerful device designed for sport and recreation use (i-gotU, Mobile Action), but costing a fraction of purpose-built animal collars. Pedometers are widely used in dairy farming for oestrus detection. However, most of these devices give inter-reading totals and not detailed timelines. One notable exception is the IceTag pedometer produced by IceRobotics. This gives the number of steps taken, and the time allocation between active, standing and lying states, for any time resolution from one second up. This device alone can be used to infer the activity timeline of grazing animals (without geolocation), and it also enables the rest category to be subdivided between stand and lie states, which may be relevant for calculations of energy expenditure. Here too, confusion of rest and graze activities is an issue. In one study, the combined deployment of Lotek GPS collars and IceTag pedometers yielded more accurate classification of activity than either device alone. Field tests are under way of a fairly new pedometer manufactured by E.N.G.S. Systems (Israel) which may offer a low-cost

alternative with limited compromise in time resolution. Various statistical approaches can be used to infer activity from GPS collar and pedometer data. Studies conducted by the author have used discriminant analysis and partition analysis. The latter usually performs at least as well as the former and is simpler to understand and apply. More advanced analytic techniques which may further reduce the misclassification rate remain to be explored. Wide-scale, multiple-site studies using a standard protocol have yet to be conducted in order to test rigorously the generality of calibration equations. Acoustic analysis is an experimental technique being developed by the author. It is based on attaching an inward-facing microphone to a hard tissue in the region of the head. The recording enables sound-producing jaw movements to be identified readily, and these can usually be classified as bites or chews. This is a promising methodology for monitoring ingestive behaviour and providing the activity timeline, although it would not be able to distinguish rest (without rumination) and travel. Primary challenges at present are automation of sound analysis and construction of robust equipment for long periods of deployment. If successful, acoustic monitoring would provide a wealth of information beyond the completely accurate identification of periods of active grazing.

Sunday 20th February, 2011
1800 – 2000 Welcome reception at the Nof Hotel for foreign invitees and attendants, the Greidinger Family & the organizing team

Monday, 21st February, 2011

0800-0930	**Registration**
0930-1000	**Opening Ceremony** Chair: Maxim Shoshany Minister of Science Prof. Daniel Hershkowitz, Technion President Prof. Peretz Lavie, Dean Of the CEE Faculty Prof. Arnon Bentur, Greidinger Family representatives, and Avi Shaviv
	1st Plenary Session Session Chair: Avi Shaviv
1000-1040	Raj Khosla *Precision Nutrient Management: Challenges and Opportunities in a Flat World*
1040-1120	Mel Tyree *An Outsider's View of Water-Stress-Sensing in Fruit Trees for Irrigation Management*
1120-1200	Marshall Porterfield *Development of Nanomaterial Platforms and Lab-On-A-Chip Technologies for Agricultural Sensing Applications*
1200-1330	**Lunch & posters** (listed at the end of the program)
	2nd Plenary Session Session Chair: Yafit Cohen
1330-1410	David Mulla *Twenty-Five Years of Remote Sensing in Precision Agriculture: Key Advances and Remaining Knowledge Gaps*
1410-1450	Urs Schmidhalter, Bodo Mistele, Loic Winterhalter, Klaus Erdle, Stefan Jungert *Developments in Precision Agriculture - Sensing the Nitrogen Status in Plants and Implementing into Fertilizing Algorithm*
1450-1530	Shmuel Friedman *Overview of Electromagnetic Methods for Evaluation of Soil Water Content and Salinity*
1530-1600	**Coffee break**

Monday, 21st February, 2011

	Auditorium		**Faculty Assembly Hall**
	Sensing & Control Systems Chair: Raphael Linker		**Fertilizers & Fertility** Chair: Urs Schmidhalter
1600-1630	John Lea-Cox *Measuring Spatial and Temporal Dynamics of Water in Soil and Soilless Substrates, to Enable Precise Scheduling of Irrigation Applications*	1600-1630	Yuxin Miao *Sensing Technology-Based Precision Nitrogen Management*
1630-1650	Josef Tanny, Rafael Rosa *Application of the Surface Renewal Technique for Estimating Evapotranspiration from an Industrial Tomato Crop*	1630-1700	Viacheslav Adamchuck *On-the-go Proximal Soil Sensing for Agriculture*
1650-1710	Shimon Rachmilevitch, Oren Shelef, Avi Golan-Goldhirsh, Tanya Gendler *Physiological Parameters of Plants as Indicators of Water Quality in a Constructed Wetland*	1700-1730	Martin Strenner, Franz-Xaver Maidl *The Effect of Wavelength and Mathematical Formula on the Result of Measurement with Different Vegetation Indices*
1710-1730	Vinay Pagay *A Novel MEMS-based Microfluidic Water Potential Sensor for Monitoring of Water Stress in Woody Plants and Soils*	1730-1750	Shaul Cohen, Ofer Levi, Ziv Mhabary, Yafit Cohen, Victor Alchanatis *Fertilization Decision-making Using Geometric Segmentation of Multispectral Images*
1730-1750	Meir Teitel, M. Atias, A. Schwartz, S. Cohen *The Greenhouse as an Open Chamber System*		

Tuesday, 22nd February, 2011

	Auditorium		**Faculty Assembly Hall**
	Soil & Water Conservation Chair: Alex Furman		**Orchards** Chair: Eran Raveh
0900-0920	André Revil *Monitoring of Pore Water Flow Using Low-frequency Electrical Methods*	0900-0930	Elias Fereres, David Goldhamer, Pablo Zarco-Tejada, Jose Jimenez-Berni, Victoria Gonzalez-Dugo, Lola Suarez *Detecting Irrigation Needs to Improve Water Management in Commercial Orchards*
0920-0940	Giorgio Cassiani, Alessandro Brovelli, Rita Deiana, Giulio Vignoli, Marco Carizzoni, Peter Dietrich, Ulrike Werban *Static and Dynamic Aspects of Non-invasive Monitoring of Soil Characteristics and Conditions*	0930-0950	Shabtai Cohen, Tal Kanety *Comparing Dendrometers, Sap Flow and Soil Water Sensors in a 3-year Persimmon Irrigation Trial*
0940-1000	Effi Tripler, Naftali Lazarovitch, Alon Ben-Gal, Zehava Yehuda, Sharon Dabach, Uri Shani *New Plant-based Feedback Irrigation Techniques for Increasing WUE of Crops*	0950-1010	Arie Nadler, Eran Raveh *Stem EC Probe: An Innovative Irrigation Controller which Activates Valves in Agronomic Crops Based on Direct Evaluation of the Plants Water Status*
1000-1020	Matteo Camporese, Mario Putti, Paolo Salandin, Pietro Teatini *Spatial Variability of CO2 Emissions in a Drained, Farmed Peatland of the Venice Watershed, Italy*	1010-1040	Amos Naor, Shaul Naschitz, Moti Peres, Yoni Gal *The Interaction between the Number of Fruit Per Tree and Water Relations in Apples – Implications for Irrigation Scheduling*
1020-1040	Naftaly Goldshleger, Eyal Ben Dor, Ido Livne *Soil Degradation Monitoring by Active and Passive Remote-sensing*		
1040-1100	**Coffee break**		
	3rd Plenary Session Chair: Maxim Shoshany		
1100-1140	Prasad Thenkabail, John G. Lyon, Alfredo Huete *Advances in Hyperspectral Remote Sensing of Vegetation and Agricultural Crops*		
1140-1220	Stuart Marsh *Remote Sensing of Rangelands – Matching Capabilities with the Need for Information in a Changing World*		
1220-1300	Ehud Behar *Israel's Vision of Satellite Remote Sensing Systems*		
1300-1400	**Lunch break**		

Tuesday, 22nd February, 2011

	Auditorium		**Faculty Assembly Hall**
	Fertilizers & Fertility Chair: Uri Yermiyahu		**Rangelands: Grazing Behavior and Productivity** Chair: Stuart Marsh
1400-1430	Urs Shmidhalter *Fertilizers and Fertility - What else should we sense?*	1400-1420	Arnon Karnieli, Tal Svoray, and Uri Gilad *Assessing &Mapping Grazing Gradients around Watering Points in Central Asian Deserts Using Satellite Image Processing and Geostatistical Methods*
1430-1500	George Vellidis, H. Savelle, G. Ritchie, G. Harris, R. Hill, and H. Henry *Using Optical Sensors to Schedule Variable Rate Application of Agrochemicals on Cotton*	1420-1440	Zalmen Henkin, Amit Dolev, Iris Schoenbaum *GPS Use for Studying Cattle Distribution in Mediterranean Rangelands*
1500-1530	Avi Shaviv, Raphael Linker, Dotan Haroush, Oz Kira, Changwen Du and Yael Dubowski *In-Situ Tracing of N Transformation in Soil and Gas Phases Using Isotopes and IR Spectroscopy*	1440-1500	Dobos Robin, Mark Trotter, David Lamb, Geoff Hinch *Correlating GPS Movement Metrics with Animal Behaviour*
		1500-1520	Eugene Ungar *How Well Can We Infer the Activity Timeline of Animals on Rangeland?*
		1520-1540	Tal Svoray, Rakefet Shafran-Nathan, Avi Perevolotsky *Space-Time Dynamics in PP of Annuals: Modeling with Geoinformatics*
1540-1600	**Coffee break**		
	Field Crops Chair: Raj Khosla		**Rangelands: Vegetation Dynamics** Chair: Tal Svoray
1600-1630	James Lowenberg-Deboer *Economics of Remote and Direct Sensing in Agriculture*	1600-1620	Moshe Shachak *The Role of Plants as Ecosystem Engineers in Resilience to Climate Change*
1630-1700	Dan Long, Jan Eitel *On-Combine Sensing of Grain and Straw Yield within Wheat Fields*	1620-1640	Liat Hadar, Tzach Glasser, Yael Navon, Avi Perevolotsky *Monitoring Effects of Controlled Goat Grazing on the Landscape: Different Approaches and Dilemmas*
1700-1720	Ofer Beeri, Shay Mey-Tal *Utilizing Daily Satellite Imagery for Farming-Oriented Information*	1640-1700	Yohay Carmel, Avi Bar Massada, Ofri Gabay, Rafi Kent, Lior Blank, Liat Hadar, Avi Perevolotsky *LIDAR & Air Photography for Fine Scale Studies of Vegetation Dynamics*
1720-1740	Moshe Meron, Joseph Tsipris, Victor Alchnatis, Yafit Cohen, and Valerie Orlov *Crop Water Stress Mapping for Site-Specific Irrigation by Thermal Imagery and Artificial Reference Surfaces*	1700-1720	Maxim Shoshany *Shrublands' Biomass Across Climatic Gradients: Modeling and Implementation Using Remote Sensing Data*
1740-1800	Yafit Cohen, Victor Alchanatis, Ronit Rud, Carl Rosen, David Mulla, Bruria Heuer, Zion Dar, Asher Levi, Roman Brikman	1720-1740	Stefan Leu, Mor Mussery, I. Lensky *Evaluating the effects of different soil management on productivity in arid zones using*

	Fusion of Hyperspectral & Thermal Images For Estimating Nitrogen and Water StatusiIn Potato Fields for Variable Rate Application		*MODIS data*
	Buses to the Nof Hotel and train station leave at 1810	1800-1900	**Discussion: The Use of Remote and Direct Sensing in Range Science** Chair: Avi Perevolotsky
19:45	**Reception at the Greidinger Family Residence - foreign attendants, theme heads, and organizers**		

Wednesday, 23rd February, 2011

	Auditorium		**Faculty Assembly Hall**
	Sensing & Control Systems Chair: John Lea-Cox		**Soil & Water Conservation** Chair: Arnon Karnieli
0900-0920	Yaron Paz, Meni Batzon, Yehushua Zeevi *Blind Separation of Infra – Red Signatures of Plants*	0900-0920	Yiftach Ben-Asher, B. Bar Yosef and R. Volinski *Monitoring Actual Evapotranspiration with Infra- red Radiometers as Input in Soil Water Transport Model for Optimal Irrigation*
0920-0940	Leonid Vulfson, Valentin Freilikher, Arthur Genis 4, Dan Blumberg, Alex Kotlyar, Jiftah Ben-Asher *Remote Sensing in Microwave and Gamma Ranges for the Monitoring of the Soil Water Content of the Root-Zone*	0920-0940	Eli Argaman, D. G. Blumberg, Jiftach Ben-Asher *Quantitative Assessment of Land Surface Processes Utilizing the Advection-Aridity Model*
0940-1000	Marina Hetz, Dan G. Blumberg, Stanley R. Rotman *Semi-Arid Vegetation Parameters from Synthetic Aperture Radar Data*	0940-1000	Shai Sela, Tal Svoray, Shmuel Assouline *Hydrological Fluxes of a Semi-Arid Sealed System and Their Relation to Vegetation Patterns*
1000-1020	Raphael Linker *Overview of Mid-infrared Techniques and Chemometrics for Soil Analysis*	1000-1020	Eran Segal, Peter J. Shouse, Scott A. Bradford, Todd H. Skaggs, Dennis L. Corwin *Field Scale Water Flow Characterization*
1020-1040	Avital Bechar, Itamar Dar, Y. Edan *A Computer Vision Algorithm for Navigation of an Autonomous Sprayer in Pepper Greenhouses*	1020-1040	Arthur Genis, Leonid Vulfson, Dan Blumberg, Michael Sprintsin, Alex Kotlyar , Valentin Freilikher, Jiftah Ben-Asher *Retrieval of Surface Roughness Parameters of Bare Soil from the ERS-2 SAR Data*
1040-1100	**Coffee break**		
	Precision Agriculture Chair: Prasad Thenkabail		
1100-1130	Anatoly Gitelson, Anthony Lawrence Nguy-Robertson, Yi Peng and Donald C. Rundquist *Remote Estimation of Crop Biophysical Characteristics: from Close Range to Satellites*		
1130-1200	Annamaria Castrignanó *Integrating Proximal Sensing and Geostatistics to Delineate Management Zones*		
1200-1230	George Vellidis, M. Tucker, C. Perry *Wireless Sensor Network Applications in Agriculture*		
1230-1300	Holger Lilienthal *Estimating Crop Parameters and LAI Through Inversion of Hyperspectral Canopy Reflectance Data*		
1300-1430	**Lunch break & poster session** (listed at the end of the program)		

Wednesday, 23rd February, 2011

	Auditorium		**Faculty Assembly Hall**
	Field Crops Chair: David Bonfil		**Orchards** Chair: Elias Fereres
1430-1500	Dan Long, Jan Eitel *Combined Spectral Indices for Remote Sensing of Leaf Chlorophyll Content of Dryland Wheat and Direct Sensing in Agriculture*	1430-1450	Stavros Vougioukas *Sensing and Intelligent Automation for Orchard Management*
1500-1520	Thomas Jarmer *Spectroscopy and Hyperspectral Imagery for Monitoring of Summer Barley*	1450-1510	Alon Ben Gal, Dilia Kool, Nurit Agam, Uri Yermiyahu, Arnon Dag *Whole-Tree Water Balance and Indicators for Short-Term Drought Stress in Non-Bearing 'Barnea' Olives*
1520-1540	Ronit Rud, Maxim Shoshany, Victor Alchanatis *Spatial-Spectral Analysis for Detection Of Salinity Effects In Cauliflower, Eggplant and Kohlrabi*	1510-1530	Nurit Agam, Yafit Cohen, Victor Alchanatis, Dilia Kool, Alon Ben-Gal *Diurnal Dynamics of Crop Water Stress Index of Olive Trees - What Does It Really Tell Us?*
1540-1600	Ittai Herrmann, Uri Shapira, Arnon Karnieli, David J. Bonfil *High Spatial Resolution Ground-Level Hyperspectral Imaging for Weed Detection*	1530-1550	Eran Raveh *The Use of the "Envelope Curve" Model for Determining the Optimal Leaf Mineral Concentration in Citrus Orchards*
1600-1620	Timea Ignat, Zeev Schmilovitch, Joszef Fefoldi, Nirit Berenstein, Bracha Steiner, Haim Egozi, Ahron Hoffman *Chlorophyll Content Measurement in Bell Pepper by VIS-NIR Spectrometry*	1550-1630	***Discussion lead by Amos Naor***
1630-1700	**Coffee break**		
1700-1830	**Closing Ceremony**: Best Poster Award and **Closing Discussion** with David Mulla, Raj Khosla, Mel Tyree, Prasad Thenkabail Chair: Victor Alchanatis		

Thursday 24th February, 2011: Professional and touristic tour for foreign participants: 0800-1730 (leaving from the Nof Hotel)

POSTER SESSIONS

Session 1: Spectral Signatures Chair: Naftali Goldshleger

Monday, 21st February, 2011: 1230-1330

Grand Water Research Institute
Annamaria Castrignano *Remote and Proximal Sensing Data Fusion to Evaluate Soil Impact on Vegetation*
Alon Eliran *Millimetre Waves, A Novel and Promising Remote Sensing Tool for Soil Sub-Surface Mapping: First Steps*
Naftaly Goldshleger *Assessing Salinity in Tomato Plants by Using Reflectance Spectroscopy*
Ittai Herrmann *Performance Analysis of Venms Bands Assessment of Lai by Red-Edge Inflection Point*
Ido Livne *Detecting and Monitoring Soil Salinity in Agricultural Lands Using Combined Hyperspectral Data and Chemical Measurements*
Rachel Lugassi *Spectral Changes at Vis-Swir Region of Burned Soils as a Tool for Monitoring Heat Induced Soil Mineralogical Changes*
Nativ Rotbart *Estimating Olive Leaf Mineral Concentration Using Spectral Reflectance*
Nimrod Schwartz *Spectral Induced Polarization (Sip) Measurement of Napl Contaminated Soils*
Fadi Kizel *Spatially Adaptive Hyperspectral Unmixing in Agricultural Areas*
Ori Agmon *Change Detection Using Unmixing in Agricultural Lands Across the Mediterranean Climate Region of Israel*
Avri Alony *Root and Rhizosphere Visualization by Laser-induced Fluorescence Imaging*
Lior Friedman *Mean Shift-based Clustering of Remotely-Sensed Data: with an Agricultural Application*
Yigal Salinger *Farmsat - An Advanced Operational System for Precision Ag in Israel; Facts And Upcoming Improvements*
Lev Karnibad *Remote Sensing of Shrublands' Patterns and Their Relationships with Biomass Along Semi-Arid Climatic Gradient*

Session 2: Monitoring Crop and Soil Conditions Chair: Naftali Goldshleger
Wednesday, 23rd February, 2011: 1330-1430

Grand Water Research Institute
Uri Dicken *Eddy Covariance Measurments of Water Vapor, Co^2 and Heat Fluxes in a Banana Screenhouse*
Liat Fassler *Early Detection of Plant Infection with Pathogenic Bacteria in Tomato and Melon Using Thermal Imaging*
Tamir Klein *Hydraulic Adaptations Underlying Drought Resistance of Pinus Halepensis*
Yoni Mekhmanderov *Examination of the Surface Renewal Technique for Sensible Heat Flux Estimates in Screenhouses*
Or Sperling *Sap Flow Measurements in Date Palm Trees – A Modified Approach for Water Stress Sensing*
Michael Sprintsin *Aerial and Ground Based Thermal Imaging for Automatic Detection of Irrigation Malfunctions*
Sharon Dabach *Numerical Investigation of Irrigation Scheduling Based on Soil Water Status*
Reut Gabbay *Investigation of The Relationship Between Soil Heterogeneity and Flow Processes in the Vadose Zone*
Vladimir Mirlas Development of a GIS Database Tool for Managing Soil Salinity Problems in Irrigation Fields in Jezre'el Valley, Israel
Dilia Kool *ET Components Investigated Individually – Testing the Two Source Model in an Arid Vineyard*
Igor Sepulveda *Water Content Distribution and Its Relation with Plants Take-Up Process*
Yunwu Xiong *Characterization and Modeling Water Infiltration and Redistribution in Repellent Soils by Moment Analysis and Artificial Neural Networks*
Shilo Navon *Automatic Recognition of Jaw Movements of Grazing Animals Using an Acoustic Sensor*
Moti Feldlite *On-Line Monitoring of Clogging Potential in Irrigation Systems*
Machtheld Steensels *Precision Agriculture in Dairy Farming: Detection of Sick Cows*
Tom Van Hertem *Precision Agriculture in Dairy Farming: Experimental Setup for a Computer Vision Based Automatic Lameness Detection System*

LIST OF PRESENTERS

Dr. Viacheslav Adamchuk, McGill University, Canada
Dr. Nurit Agam, Gilat Research Center Agricultural Research Organization, Israel
Mr. Ori Agmon, Technion- Israel Institute of Technology, Israel
Dr. Victor Alchanatis, Agricultural Research Organization, Israel
Mr. Avri Alony, Technion- Israel Institute of Technology, Israel
Dr. Eli Argaman, Ministry of Agriculture & Rural Development, Israel
Dr. Avital Bechar, Agricultural Research Organization, Israel
Dr. Ofer Beeri, Agam Advanced Agronomy, Israel
Prof. Yiftach Ben Asher, AgriEcology Group, Israel
Dr. Alon Ben Gal, Gilat Research Center, Israel
Dr. Matteo Camporese, Università degli Studi di Padova, Italy
Prof. Yohay Carmel, Technion- Israel Institute of Technology, Israel
Prof. Giorgio Cassiani, Università di Padova, Italy
Dr. Annamaria Castrignano, CRA-SCA, Italy
Dr. Shaul Cohen, Ben-Gurion University of the Negev, Israel
Dr. Shabtai Cohen, Agricultural Research Organization, Israel
Dr. Yafit Cohen, Agricultural Research Organization, Israel
Mr. Sharon Dabach, Hebrew University of Jerusalem, Rehovot, Israel
Mr. Uri Dicken, Agricultural Research Organization, Israel
Dr. Robin Dobos, University of New England, Australia
Mr. Alon Eliran, Tel-Aviv University, Israel
Ms. Liat Fassler, Hebrew University of Jerusalem, Rehovot, Israel
Dr. Moti Feldlite, Israel Water Works Association, Israel
Dr. Elias Fereres, University of Cordoba, Spain
Mr. Lior Friedman, Bar-Ilan University, Israel
Dr. Shmulik Friedman, Agricultural Research Organization, Israel
Ms. Reut Gabbay, Technion- Israel Institute of Technology, Israel
Mr. Arthur Genus, Ben-Gurion University of the Negev, Israel
Prof. Anatoly Gittelson, University of Nebraska-Lincoln, United States
Dr. Naftali Goldshleger, Tel-Aviv University, Israel
Ms. Liat Hadar, Ramat Hanadiv Nature Park, Israel
Dr. Zalmen Henkin, Agricultural Research Organization, Israel
Mr. Ittai Herrmann, Ben-Gurion University of the Negev, Israel
Ms. Marina Hetz Ben-Gurion University of the Negev, Israel
Dr. Thomas Jarmer, University of Osnabrueck, Germany
Mr. Lev Karnibad, Technion- Israel Institute of Technology, Israel
Prof. Arnon Karnieli, Ben-Gurion University of the Negev, Israel
Dr. Raj Khosla, Colorado State University, United States
Mr. Fadi Kizel, Technion- Israel Institute of Technology, Israel
Dr. Assaf Klar, Technion- Israel Institute of Technology, Israel
Mr. Tamir Klein, Weizmann Institute of Science, Israel
Ms. Dilia Kool, Agricultural Research Organization, Israel
Dr. John Lea-Cox, University of Maryland, United States
Dr. Stefan Leu, Ben-Gurion University of the Negev, Israel

Dr. Holger Lilienthal, Institute of Crop and Soil Science, Israel
Dr. Raphael Linker, Technion- Israel Institute of Technology, Israel
Mr. Ido Livne, Tel-Aviv University, Israel
Dr. Dan Long, Columbia Plateau Conservation Research Center Oregon, United States
Dr. James Lowenberg-DeBoer, Purdue University, United States
Dr. Rachel Lugassi, Tel-Aviv University, Israel
Prof. Stuart Marsh, University of Arizona Tucson, United States
Mr. Yoni Mekhmanderov, Agricultural Research Organization, Israel
Dr. Moshe Meron, Agricultural Research Organization, Israel
Dr. Yuxin Miao, China Agricultural University, China
Dr. Vladimir Mirlas, Ministry of Agriculture and Rural Development, Israel
Dr. David Mulla, University of Minnesota, United States
Dr. Amir Mussery, Judea Research and Development Center, Israel
Dr. Arie Nadler, Agricultural Research Organization, Israel
Dr. Amos Naor, Golan Research Institute, Israel
Mr. Shilo Navon, Agricultural Research Organization, Israel
Mr. Vinay Pagay, Cornell University, United States
Prof. Yaron Paz, Technion- Israel Institute of Technology, Israel
Prof. Marshall Porterfield, Purdue University, United States
Dr. Shimon Rachmilevitch, Ben-Gurion University of the Negev, Israel
Dr. Eran Raveh, Agricultural Research Organization, Israel
Prof. Andre Revil, Colorado School of Mines, United States
Mr. Nativ Rotbart, Agricultural Research Organization, Israel
Ms. Ronit Rud, Agricultural Research Organization, Israel
Dr. Yigal Salinger, GIS-Stav, Israel
Prof. Urs Schmidhalter, Technische Universität München, Germany
Mr. Nimrod Schwartz, Technion- Israel Institute of Technology, Israel
Dr. Eran Segal, Gilat Research Center, Israel
Mr. Shai Sela, Ben-Gurion University of the Negev, Israel
Mr. Igor Sepulveda, Technion- Israel Institute of Technology, Israel
Prof. Moshe Shachak, Ben-Gurion University of the Negev, Israel
Prof. Avi Shaviv, Technion- Israel Institute of Technology, Israel
Prof. Maxim Shoshany, Technion- Israel Institute of Technology, Israel
Mr. Or Sperling, Ben-Gurion University of the Negev, Israel
Mr. Michael Sprintsin, Agricultural Research Organization, Israel
Mr. Machteld Steensels, Agricultural Research Organization, Israel
Ing. Martin Strenner, Technische Universität München, Germany
Dr. Tal Svoray, Ben-Gurion University of the Negev, Israel
Dr. Yoseph Tanny, Agricultural Research Organization, Israel
Dr. Meir Teitel, Agricultural Research Organization, Israel
Dr. Prasad Thenkabail, University of Arizona, United States
Mr. Effi Tripler, Southern Arava R&D, Israel
Prof. Mel Tyree, University of Alberta, Canada
Dr. Eugene Ungar, Agricultural Research Organization, Israel
Mr. Tom Van Hertem, Agricultural Research Organization, Israel

Prof. George Vellidis, University of Georgia, United States
Prof. Stavros Vougioukas, Aristotle University, Greece
Mr. Leonid Vulfson, Bar-Ilan University, Israel
Mr. Yunwu Xiong, Hebrew University of Jerusalem, Rehovot, Israel

Dahlia Greidinger

Dalia was born in 1926 in Neve Zedek, Tel-Aviv; she was a fifth-generation Israeli. Dahlia studied Chemistry at Lausanne University in Switzerland where she obtained her M.Sc. with distinction. In 1949, Dalia returned to Israel and received the appointment of first editor of the Israel Scientific Council magazine. During her working period there, she met Coleman Greidinger, and in October, 1950, they were married. In 1951, she started working as a teaching and research assistant at the Technion. In 1958, already a mother of two, she received her D.Sc.

In 1959, Dalia started working in what became her second home - Fertilizers & Chemicals Ltd.. Dahlia came into the job without any previous experience in industry or trade, but as head of a research group, she developed new ideas, and found practical applications for the food industry, textiles and pharmacology. In 1969, by then a mother of four, she was appointed to the position of Director of Research and Development, and was made a board member. Dr. Dahlia Gredinger, as a senior scientist, was responsible for many landmark developments in the chemical industry in Israel. She contributed to the fight against worldwide hunger by developing innovative fertilization systems. To her credit is a long line of patents and scientific publications. As a "Deshanim" board member, Dahlia contributed much in areas which were not always in her line of occupation, in the fields of both human and labor relations, and even economic and organizational decisions.

Besides her widespread professional activities, Dahlia also found time to be active in public affairs. For many years she was a member of the Soroptimist movement. Between the years 1963-64 she served as President of the Haifa Club and as its representative on the national council. In 1968 she was appointed President of the Israeli Union of Soroptimist Clubs for a period of two years, and from 1972 she served as member of the European Committee for Expansion. She was also active in the Association of Academic Women and in the Anti-Cancer Association.

Parallel with her widespread scientific and public activities, which she fulfilled with great devotion, Dahlia was a devoted wife and mother. All visitors, from near or far, were greatly impressed by her warm and courteous hospitality.

In 1969, Dahlia contracted cancer and fought the illness very courageously for nearly ten years. Until her last day, she continued with her work. Only a few days before she died, Dahlia was still making plans, thinking of every detail, enthusiastic as always, arranging meetings at home and planning for the future.

The Dahlia Greidinger Fertilizer Research Fund is one of the foundations commemorating her.