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Capacitive Sensors and Breakthrough Curves in Automated Irrigation for Water and Soil Conservation

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Shortness of water resources is the dominant criterion that dampens agricultural expansion in Egypt. Ten times population increase was recorded versus twice increase in the cultivated area during the last 100 years. Significant increase in freshwater supply is not expected in the near future. Consequently, a great deal of water-conservation is required to ameliorate water-use efficiency and to protect soils against sodicity under the prevailing arid-zone conditions. Modern irrigation (pivot, drip and sprinkling) was introduced during the last three decades in newly cultivated lands. However, this was done without automated watering. Moreover, dynamic chemical profile data is lacking in the cultivated lands. These current water conditions are behind this work. Two experimental procedures were used for a conjunctive goal of water and soil conservation.

The first procedure used the resonance of analog-oscillators (relative permittivity sensors) based on capacitive Frequency Domain Reflectometry, FDR. Commercially available FDR sensors were calibrated for three soil textures, and solenoids were used to automatically turn on and off irrigation pipes in three experimental plots (via low power AC latching-valves on relay solid-state boards connected to sensors; the valve got closed when soil became sufficiently moist near saturation and opened before reaching wilting point as the relay contacts were defined by variable-resistor on board after sensor calibration). This article reports the results of sensor mV readings versus soil-moisture in the linear parts of calibration diagrams, for known moisture contents from wilting point to saturation, fitted as "power-law of dielectric mixing". The results showed close to optimum watering at soil-surface in the nursery beds when the sensors were sampled every 10 minutes to update the relays. This work is planned to extend to different sensors and drippers for soils with field crops / fruit trees to account for aspects of concern when such sensors are used in farmers' fields.

The second procedure was Breakthrough Curve (BTC) lab-method to follow the fate of chemical composition of water draining out of Ca-saturated soil columns and Exchangeable Sodium Percent, ESP, in soil materials under saturated-flow. The work was run on five packed soil-columns under hydraulic-gradient of about 6 in fine-grained soil materials (Nile clay-sediments) wetted with five NaCl aqueous solutions (10, 25, 50, 75 and 100 mEq/l). The results revealed the removal of 40 to 80% of sodium from irrigation water after 6 to 8 pore volumes flowed out in about 12 hours with the highest removal from the most dilute solution. Rapid increase of ESP was observed when the inlet solution had moderate to high TDS whereas the dilute solution (10 mEq/l) has resulted in no soil chemical degradation. The results were extrapolated to field situation and showed that Nile clayey soil would never get sodic (ESP>15) when wetted with high quality water regardless the water application duration whereas only 1-4 year of irrigation with moderate to poor-quality water (as takes place under perennial irrigation) would result in ESP increase to 15 and much higher values. A secondary but important outcome of BTC experiments was that marginal sediments could be used in multi-column cells (6 to 8 columns) to improve water-quality through removal of Na+ ions from water, whereas anions could be removed by positively-charged resins and the cells could be recycled in a proposed prototype scheme.