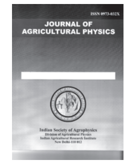
Vol. 20, No. 2, pp. 185-190 (2020)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in



Research Article

Soil Moisture Variability and Tree Water Status *vis-à-vis* Productivity in Fruit Orchards as Estimated by Unmanned Aerial Vehicle, Drones, RADAR Technologies

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ABSTRACT

Soil moisture is the most important factor supporting livelihood in various agro-ecosystem. Estimation of moisture content was thus obvious need in any precision farming cum productivity enhancement centres as evapotranspiration varies in different weather scenarios. Variability during critical phenological stages determines bearing capabilities; vertical and horizontal wetting front contributes to water optimization. Advanced technologies using RADAR, UAV, drones, artificial neural networking etc. are necessarily used for imagery estimation of soil moisture *vis-à-vis* spectral information of tree water status. The crucial role of all these advanced technologies is summarized herewith with respect to key soil moisture conservation.

Key words: Soil moisture variability, moisture cum productivity, wetting zones *vs* evapotranspiration, technological solution

Introduction

The most important factor supporting livelihood and productive potential in different agri-horti-silvi-pastoral ecologies is the soil moisture (Ekka *et al.*, 2017). Drier the situation in peak fruiting stages, lower is the probability of good production level as it enhances scope of fruit drop, fruit cracking and restricts fruit growth etc. Therefore, maintenance of optimum soil moisture is always key factor for best management policy as it is highly influenced by the action of weather (Adak *et al.,* 2017; Tsoulias *et al.*, 2020). Advancement in vertical layers or horizontal direction also is an indication of wetting front movement in right direction for right cause. Plant/ tree water status was thus an indicator for stresses which can be easily detected and resolved. The water content profiler can be used for vertical soil water content measurement in a more precise way than gravimetric or neutron probe meter keeping in view of data reliability (Vienken *et al.*, 2013). The soil-atmospheric interaction also plays crucial role in the stress related issues (Gonzalez-Dugo *et al.*, 2012). Sometimes, soil-tree atmosphere continuum modelling approach was used to estimate the tree water relationships (Rings *et al.,* 2013). Peddinti *et al.* (2018) described the root dynamics in mandarin orange trees while Blanco *et al.* (2019) depicts the yield and quality changes in sweet cherry as depended factor for soil moisture. A number of methodologies are applied to estimate soil moisture variability. Such estimation is an indication of spatio-temporal life cycles of moisture content in orchards. Gillreath-Brown *et al.* (2019) suggested soil moisture proxy model-a

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geospatial method for estimating soil moisture variability while grapevine water status was assessed using hyperspectral imaging (Pôças *et al*., 2017). All these information suggested possibility of precise scientific measurement, prediction of soil moisture variability cum tree water status.

Insights into the soil moisture variability for ensuring productivity

Table 1 showed interaction of weather-soil moisture cum productivity analysis. Optimum moisture conservation in root zone is thus crucial for productivity cum sustainability. Depth of water table is important for precision farming and many a times, sensors were installed to find out soil water status cum potential to avoid moisture stress. Hedley *et al.* (2013) nicely describes modelling approach through electromagnetic surveys for estimation of soil moisture status while Silva *et al.* (2012) developed better root zone water conservation in banana. In this context, suspension lysimetric system recommended for better understanding in soil-water flux movement (Beeson, 2011). Soil water potential *vis-à-vis* water extraction pattern had tremendous impact on pear (Janssens *et al.,* 2015); avocado (Moreno-Ortega *et al.,* 2019). In order to maintain optimum soil moisture in sandy soil, four drip laterals and irrigation frequency (four days per week) significantly influenced exportable fruit size of blueberry (Holzapfel *et al.,* 2015). Fig. 1 showed field scale variability of soil moisture in mango orchards. Adak *et al.* (2019) nicely explained the need for soil and water conservation measures for root zone water maintenance and orchard sustainability. Gush *et al.* (2019) narrated the water foot print (total water footprint of 212.1 m^3 t^{-1} with water productivity of 4.72 kgm^{-3}) in apple orchards. For precise water budgeting, Chebbi *et al.* (2018) quantified tree transpiration, soil moisture and evapotranspiration during three contrasting climatic condition in dry farming Tunisia olive orchard. Thus, water

Table 1. Analysis of weather-soil moisture *vis-à-vis* yield variation

References	Outcomes	Strategy	Orchards
Singha *et al.*(2016)	Variability in soil moisture, temperature and enzymatic activities were quantified for precise management	Yield enhancement through high density guava	Guava
Käthner *et al.*(2017)	Estimation of apparent electrical conductivity, tree water status by crop water stress index, cumulative water use efficiency of 2.362 to 2.521 g L^{-1}.	Precision irrigation scheduling	Plum
Liao *et al.*(2019)	Evaluated soil moisture availability during cherry growth stages. In leaf development, flowering and maturation stages, water contribution ratio in the main root zone was significantly greater by 11-28%, 49-59% and 16-33% respectively in micro-irrigation with mulch treatments than furrow.	Furrow and micro irrigation regimes	Cherry
Millán *et al.*(2020)	Generated information on apparent electrical conductivity and normalized difference vegetation index maps, temporal trends of soil moisture with seasonal stem water potential; yield of 5490 to 21478 kg ha^{-1} and water productivity of 23.66 to52 kg m^{-3}.	For establishment of regulated deficit irrigation strategy	Olive
Martin-Gorriza *et al.* (2020)	Temporal changes in soil moisture, temperature, ecosystem, aboveground and belowground respiration was quantified.	Quantification of biotic and abiotic factors in irrigated Citrus orchard	Citrus

Table 2. Tree or soil water status /stress estimation using spectral technologies

References	Outcomes	Strategy	Orchards
Stagakis *et al.* (2012)	Water stress and fruit quality was assessed through structural, chlorophyll and photochemical indices.	Regulated deficit irrigation	Orange
Gonzalez-Dugo *et al.* (2013)	High resolution airborne thermal imagery assessed stem water potentials and water stress index	Precise irrigation management	Five fruit tree species
Rallo *et al.* (2014)	Leaf water potential was estimated at tree and leaf canopy levels. Moisture spectral index and normalized difference water index were best.	Water stress detection via spectral signatures	Olive
Gaur *et al.* (2017)	Remote sensing pixel resolution and NDVI corrector reasonably estimate spatial variations in evapotranspiration in orchards	Developing efficient irrigation scheduling	Almond and pistachio
Balbontín *et al.* (2017)	Stem water potential, water stress quantified using NDVI and crop coefficient values	Assessing table grape irrigation requirements	Grape
Poblete *et al.* (2017)	Quantified midday stem water potential spatial variability through artificial neural network models derived from UAV based high resolution multispectral images	Water status variability measurement using multispectral information	Vineyard

budgeting cum moisture variability has impacts on fruit orchards.

Estimation of moisture using advanced technologies

Remote sensing and other biophysical attributes were widely applied to estimate soil moisture variability and tree/plant water status as well (Table 2). It depicts precisely spectral information both from soil and plant under different hydrothermal regimes. Artificial neural networking, fuzzy logy, modelling, unmanned aerial vehicle (UAV), radar, hyperspectral imaging system were put in place for scientifically prediction of soil-plant-environment interaction across different time and space scale. Moran *et al.* (2004) estimated variability in soil water in watershed area using synthetic aperture radar of 10 to 100 m scale and surface models. The water stress detection in apple trees using spectral reflectance was evaluated for providing decision support to future water management (Kim *et al.,* 2011). Zarco-Tejada *et al.* (2012) used chlorophyll fluorescence and photochemical reflectance index to quantify water stress in citrus orchard using UAV based thermal camera and hyperspectral imager. Three D electrical resistivity tomography showed clear picture of subsoil and tree root activity in apple orchards (Boaga *et al.,* 2013). Ding *et al.* (2013) measured diurnal and seasonal surface latent heal flux and sensible soil heat flux in a banana plantation and observed difference among the components as

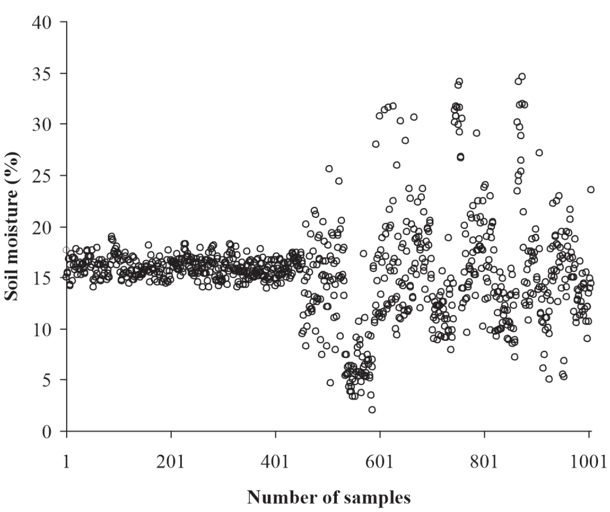

Fig. 1. Scattered distribution of soil moisture content (n=1006) in Dashehari mango orchards across different depths, moisture regimes and seasons in ICAR-CISH, Rehmankhera experimental farm of Lucknow

influenced by variable rate of interaction. Meteorological and soil moisture do impact on the stem water potential and it can be easily detected by artificial neural networks models (Martí *et al.,* 2013). Therefore, smart irrigation management was thus needed to avoid water stress in soil and plant as detection by various sources and tools (Goap *et al.,* 2018).

Conclusion

The current analysis showed soil moisture variability do exited across various hydrothermal regions under the impact of meteorological actions. Profile soil moisture and seasonal or temporal and spatial stem water potential was quantified. Remote sensing methodologies were applied to detect water stress. Spectral signatures were scientifically crucial in generating useful information for precise water management. Latest scientific information on soils, yield, quality and other parameters are obvious need for precision farming.

Acknowledgement

Director, ICAR-CISH, Lucknow is duly acknowledged for his motivation in theme based scientific analysis in precision farming research. All other colleagues and unknown reviewers were also acknowledged for their positive support and inspiration to do excellence in science.

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Received: September 19, 2020; Accepted: December 28, 2020