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Research Article

Soil Hydraulic Properties in Diverse Fruit Orchard Ecosystem – An Analysis

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ABSTRACT

Knowledge of hydraulic properties in soil as well as hydraulic architecture in tree is important for successfully running the precision farming. Hydraulic conductivity, bulk density, water holding capacity, compaction, aggregate stability etc. are known to vary under different water regimes, tillage implementation, soil management, etc. Land use management is also known to have profound impact on hydraulic properties. Tree hydraulic structures act as a function of management practices applied. Both the soil and tree components are dependent on the abiotic stresses existed in the field or green house condition. The present paper focuses on the variability of soil hydraulic properties over a vast range of production system under different agri-horti ecosystem.

Key words: Hydraulic properties, Moisture regime, Soil management, Land use option, Tillage components

Soil hydraulic conductivity (K_s) is an important factor essentially determines the water flow within the soil. The water uptake and its continuum in soil-tree based on locations were actually governed by the hydraulic properties. It acts as a dependent factor and is known to vary under diverse hydraulic properties acting within the soil ecosystem. Hydraulic conductivity is a function of pore size distribution, pore conductivity, bulk density (ρ_d), compaction, and water holding capacity etc. undergoes spatial and temporal variations; of course it varies with the textural classes of soil and is associated with thermal properties but the structural arrangement determines the rate of water flow in soil. The pore water conductivity is also related to ambient temperatures and varies with moisture regimes (Adak *et al*., 2014; Reynolds *et al*., 2009). Both saturation and unsaturation in the soil layer particularly in the root zone area indicate the status of the tree either to withstand or succumb to abiotic stresses. The adaptive capability of the trees is also playing a major role under such condition. Even under flooding situation, the xylem flow, transpiration, hydraulic capacities are known to modify/acclimatize over period of time to long standing plantations. Produce in plantations under diverse ecological regimes was in random nature; some are at full capacity, some are at middle or low. Under such situation, fine tuning of the existed technologies and management is needed to overcome the detrimental effects and also to improve the hydraulic architectural situations for sustaining better crops (Tardaguila *et al*., 2011). Interdisciplinary approaches consisting of geology, hydrology, biology and other related branches are needed to understand the magnitude and variability of K_s (Naganna *et al*., 2017).

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Variability of hydraulic conductivity in different moisture regimes

Dynamic change in saturated and unsaturated hydraulic conductivity determines the ways of water flow. Root zone layer and rhizospheric manipulations plays significant role in water movement and impacts on hydraulic conductivity (Kroener *et al*., 2018). The biopores, micropores are significantly influencing the K_s (Table 1). Soil organic matter is significantly correlated with the $K_{s;}$ with higher the soil organic carbon content better is the K_s. Soil moisture regimes actually changes the moisture dynamics in soil through which hydraulic properties are expected to vary; infiltration and percolation of water is also dependent on K_s. Improved drainage system in soil is also encompasses the K_s through which water dynamics can be recognized; patterns of water uptake varies from soil to soil (Olsson and Rose, 1988). Changes in K_s in the vadose zone is an important aspect to study as the water infiltrated and move through the root zone layer; microbial and temperature interactions taken plays to influence the $K_{s.}$ The temporal changes in hydraulic properties (total porosity, macro-porosity, bulk density, available water capacity etc.) were recorded from 15 strawberry fields grown under drip fertigation in Brazil (Bamberg *et al*., 2011). Management options suggested for growers is to apply water supply gradually at increasing rate through fertigation towards the end of crop cycle rather than applying constant rate throughout the growing season. Zeng *et al*. (2013) observed temporal variations in K_s in grape field with significantly higher values in sandy loam soils as compared to clay loam. Normally K_s remains high at initial level and gradually decreases from April to September. Abd Rashid *et al*. (2015) observed different hydraulic properties in the stemflow and throughfall regions under the oil palm trees with higher K_s in stemflow area than throughfall area. The $K_{s,}$ ρ_b, porosity was estimated to be varied in loamy sandy and sandy loamy textured soils with intensive managed orchards and required special attention to maintain the uniformity in soil physical properties (Paltineanu *et al*., 2016). Root, shoot, leaf with petiole hydraulic conductivity was measured in young pear tree under different drip irrigation system and it was inferred from the study that alternate drip irrigation system enhances the total hydraulic conductivity and water use efficiency required for water conservation (Yang *et al*., 2013). Sometimes, high predawn leaf water potentials in the range of -0.40 to -0.55 MPa recorded during the dry seasons

Table 1. Role of various water regimes on hydraulic properties variations

Soil type	Country	Fruit orchard	Changes in hydraulic properties observed	Regimes involved	Reference
Silty loam (Andosol)	Chile	Blueberry	water storage capacity, water-filled macrospores, porosity, bulk density (ρ_d) and K_s	Drip irrigation	Dec and Dörner (2014)
Loamy (Calcaro-Calcic Chernozem)	Romania	Peach	Compaction, macro-porosity (pores >50 µm, ρ_d and K_s	Normal management	Paltineanu *et al*. (2016)
Sandy Clay Loam	Japan and Thailand	Mango	Soil water retentivity, K_s	Soil water regime	Yuge *et al*. (2013)
Silt loam	Washington, USA	Sweet cherry	Tree hydraulic components (stem-leaf and root-stem), leaf water potential	micro-sprinkler irrigation	Oyarzún *et al*. (2010)
Local soil	Israel	Date palm	Specific hydraulic conductivity, flux density, sap flow	Irrigation	Sperling *et al*. (2012)
Sandy loam	Australia	Mango	sap flow density, sap flow	Sprinkler irrigation	Lu *et al*. (2000)

may not be favourable for chestnut production in Northeastern Portugal but water potentials from -1.46 to -1.72 MPa under an extremely dry year limited the nut production (Martins *et al*., 2010). Naor *et al*. (2013) correlated crop load on water relations; high crop load increased stomatal conductance and decreased stem water potential relative to low crop load at low and medium irrigation rates. The lowest and highest irrigation rate resulted into commercial oil yield of 1.99 and 3.06 t ha^{-1} respectively in Koroneiki Olive orchard. Moisture regimes and soil processes are thus significantly addressed the yield variations in 3-year-old Merlot vineyard grown in the semi-arid Okanagan Valley, British Columbia (Hannam *et al*., 2016). In presence of a shallow water table, application of 20 to 40% ET_c improved the yield (13-16 t ha^{-1}) of 'Carménère' grape in Chile (Jara *et al*., 2017). Further, maintenance of spontaneous herbaceous vegetation without irrigation enhanced productivity of chestnut stands as compared with the conventional tillage system and the no tillage system with seeded pasture. El-Shazly *et al*. (2014) measures the total and relative leaf water contents under three irrigation treatments (100, 75 and 50% ET_c) in four Fig cultivars (*Ficus carica* L.) and in terms of water dynamics, cultivars followed the trend as Sultani> White Adissi> Conadria> Kadota. Variations in bulk density, porosity, θ, SOC content and Yield (9.2 to 16.1 t ha^{-1}) was noted in sapota grown on sandy loam soils with irrigation and mulch (Tiwari *et al*., 2014). The maximum value of bulk density and minimum value of porosity was found as 1.72 g cm^{-3} and 35.1% respectively in ring basin irrigation + without mulch. The minimum value of bulk density and maximum value of porosity was found as 1.59 g cm^{-3} and 40.0% respectively in the drip irrigation + plastic mulch. The organic carbon in surface soil (0-30 cm) was estimated as 2.50 g kg^{-1} to 4.79 g kg^{-1}, 0.66 g kg^{-1} to 1.73 g kg^{-1} (sub surface soil) and 0.48 g kg^{-1} to 1.24 g kg^{-1} (60-90 cm).

Tree hydraulic architecture in root, leaf and stem also plays pivotal role in fruit production system as a function of θ. Both diurnal and seasonal variations in θ, K_s and other associated parameters tend to influence the water relations (Table 1). Seasonal vartions in volumetric soil water content (θ_v), predawn leaf water potential (Ψ_{pd}), stomatal conductance (g_s), osmotic water potential at full turgor (Ψ_π^{100}), osmotic water potential at turgor loss point (Ψ_π^{100}), relative water content at turgor loss point (R_0), and symplastic water fraction at full turgor (R_s) were recorded in pear leaves under different moisture regimes (Marsal and Girona, 1997). It was concluded that changes in leaf tissue water relations as a result of leaf acclimation to water stress are unlikely to facilitate maintenance of fruit productivity under drought. Basile *et al*. (2003) computed that the root system accounted for 67-77% of whole-plant hydraulic resistance in peach trees when plants were grafted on a vigorous or a dwarfing rootstock. Nardini *et al.* (2006) concluded that reduced root hydraulic conductance may explain rootstock-induced dwarfing in olive. Whole-plant hydraulic conductance (K_{plant}) of olive was between 5.0 and 7.0×10^{-5} kg s^{-1} m^{-2} MPa^{-1}. Further, it was observed that root systems accounted for 60-70% of plant hydraulic resistance, whereas hydraulic resistance of the graft union was negligible. Hydraulic conductance of scion dwarfing root systems was up to 2.5 times less than that of vigorous scion growth root systems. The xylem characteristics, hydraulic architecture in orange, olive and plum tree were studied for accurate sap flow measurements (Fernández *et al*., 2006). Lechaudel *et al*. (2007) noted the differences between hydraulic conductivity between the stem and the fruit, xylem water potential of the stem and fruit water potential in mango fruit. Study on elastic (function of elastic modulus and variation in turgor pressure; shrinkage and swelling) and plastic growth (generally zero during the day) of mango fruit growth indicated fruit expansion in the night when both plastic and elastic growths were positive. The hydraulic conductivity of the mango fruit estimated as 0.570 g cm^{-2} MPa^{-1} h^{-1}. Similarly, maximum stomatal conductance, mesophyll conductance and stem-to-leaf hydraulic conductance were determined in leaves and shoots in mature almond tree under full, deficit irrigation and rainfed conditions in a semi arid climate. Based on three years study, it was inferred that the changes in the crown architecture influence the water stress modulates the irradiance-elicited plasticity of almond leaves and such changes lead to adjustment in photosynthetic capacity as water stress intensifies (Egea *et al*., 2012). Different types of soil (clay and sandy loam) and water quality (treated wastewater) also impacted the root hydraulic conductivity in Citrus root system; with reduced root hydraulic conductivity in clay soil and with treated waste water reductions were noted in all root orders in clay but only of the lower root orders in sandy loam soil (Paudel *et al*., 2016). Abiotic stress (soil moisture regimes) significantly changing the seasonal variations in leaf stomatal conductance and predawn water potential and consequently fruit quality parameters in Pomegranate (Noitsakis *et al*., 2016). Thus, it was evidenced that the soil and tree hydraulic architecture acts as function of abiotic stress related conditions and were known to impact on yield variations.

Dynamics of hydraulic properties under different soil management

Soil management always contributes to the dynamics of hydraulic properties in soil mostly by the response of different added treatments (Castellini *et al*., 2014; Xingwu *et al*., 2015). Integrated nutrient management or organic management and other soil management practices are responsible for variability of K_c, ρ_d, WHC etc (Table 2). Positive effects were also noted. Mostly it was revealed that aggregate stability, WHC increased through organic management. Water retention and soil moisture (θ) content enhanced through vast range of organic treatments to horticultural soil or media. Changes in physical properties across different depths (surface, root zone as well as deeper depths) also observed. It was found that addition of minute quantity of organic or micronutrients there was many fold increase in SOC, enzymatic reactions etc. Orchard

Table 2. Impact of different soil management practices on hydraulic properties

Soil type	Country	Fruit orchard	Changes in hydraulic properties recorded	Management practices involved	Reference
Newly reclaimed sandy soil	Egypt	Pomegranate	Soil physical, chemical properties and fruit yield	Soil conditioner (polyacrylamide polymer) @1000 g/tree along with irrigation water level 85% of ET_o (4105 m^3/fed)	Farag *et al*. (2017)
Clay loam (hypercalcic Calcisol)	SE Spain	Almond	Wet aggregatestability, soil organic carbon, moisture content etc.	Four types of soil management	Ramos *et al*. (2011)
Silt loam or silty clay loam	Ohio, USA	Strawberries	Yield and yield attributes	Different rates of vermicompost	Arancon *et al*. (2004)
Silty-clay loam (mixedmesic Udic Hapludalf)	Ithaca, N.Y., USA	Apple	Soil water potential, SOC, $\rho_{d,}$ pore size distribution, θ and K_s	Ground cover management system	Merwin *et al.* (1994)
Sandy loam	Lucknow, India	Guava	Soil physical properties	Organic + inorganic system	Adak *et al*. (2017)
Sandy loam	Italy	Olive	Soil porosity, structure, leaf water potential, infiltration, K_s and SOC	Permanent natural cover or tillage	Gucci *et al*. (2012)

soil management practices involving retention of grasses or removal of grass from the entire orchard floor either by cultivation or by the use of herbicides have shown impacts on soil hydraulic properties (Haynes, 1980-81). It was observed that cultivation resulted into decreased water aggregate stability, bulk density, tree root density and increased saturated hydraulic conductivity, macro-porosity and total porosity than with grass while herbicide application had reverse results. Tisdall *et al.* (1984) found high infiltration rates and macroporosity (14%) to a depth of 37 cm after 9 years of cultivation in a Tatura system of soil management (soil modification to 60 cm depth, hilled surface soil, subsequent non-cultivation, straw mulch and frequent irrigation). Tisdall and Hodgson (1990) also suggested for ridge tillage through which better productivity can be obtained in poorly drained alfisols and vertisols in Australia as the system related to air-filled porosity and θ conservation. Generally, biological clogging of soil pores tends to decrease hydraulic conductivity over a land mass or soil, however addition of wastewater may be beneficial in maintaining the soil hydraulic conductivity (Magesan *et al.*, 2000). Soil management with sewage sludges showed enhancement in soil organic matter components, aggregate stability and biological activity in a horticultural soil (Albiach *et al.*, 2001). Many a times, orchard floor management also impacting the soil compaction in pecan tree (Foshee *et al.*, 1997), soil properties in olive groves (Aranda *et al.*, 2011), soil physical properties in high density mango orchard (Adak *et al.*, 2016). Different organic amendments (poultry manure, rice mill wastes and their combinations) and inorganic amendments comprised of inorganic fertilizer (NPK) improved mesoaggregates fraction and after six month onwards, proportions of microaggregates increased in a degraded tropical Ultisol in southern Nigeria. Significant correlation between organic carbon and mean-weight diameter of the aggregates was also envisaged (Adesodun *et al.*, 2005). Vogeler *et al.* (2006) recorded higher macroporosity in organic management and low soil strength as a function of different soil management practice and compaction zone in Apple orchard. Deurer *et al.* (2008) reported that soil C management accounted for 0 to 81% of the degradation or enhancement of biophysical soil properties like θ, aggregate stability, and pore diameter etc. in an integrated and organic Apple orchard system in New Zealand. Organic amendments consisting of vermicompost with compost and/or bone meal mixtures are observed to improve soil quality (González *et al.*, 2010). For enhancement of resistance of silty loam soil to water erosion, addition of urban compost amendments (municipal solid waste, biowaste compost and co-compost of sewage sludge and green wastes) and farmyard manure amendment @4 Mg C ha^{-1} every other year improved the aggregate stability and other properties (Annabi *et al.*, 2011). Asghari *et al.* (2011) found improvement in physical quality of sandy loam soils using soil conditioners like vermicompost, cattle manure, biological sludge and polyacrylamide etc. Productions of nursery soils rich in nutrients are also equally important from view point of seedling, ornamental, flowers, vegetables and shrubs cultivation. In a three years study with duck manure-sawdust, potato cull-sawdust-dairy manure or paper mill sludge-bark composts applied to a Plano silt loam soil at different application methods *viz*., 2.5 cm of compost incorporated into the top 15 cm of soil (incorporated-only) or 2.5 cm of compost incorporated + 2.5 cm of compost applied over the soil surface (mulched) on three shrub species, Gonzalez and Cooperband (2002) observed that compost amended treatments increased saturated hydraulic conductivity (K_{sat}) sevenfold over the non-amended control. Higher field moisture retention capacity was recorded in the incorporated treatments than mulched and non-amended control treatments. About 15%-21% higher total soil carbon, decreased (ρ_b), greater aggregate stability and the formation of larger aggregates (θ_v) in mulched treatments as compared to the incorporated-only and no-amendment control treatments was evidenced. Ofcourse soil management impacts on pore size distribution and it acts as a soil physical quality index for agricultural and pasture soils (Shahab *et al.*, 2013). Therefore, spatio-temporal variability of PSD also needs to be understood. Spatial variability of soil physical and chemical properties was mapped and higher yield (2.6 t ha^{-1}) was obtained through site-specific nutrient management than conventional system (2.5 t ha^{-1}) in a commercial pears production (Konopatzki *et al.*, 2016). Rahman *et al.* (2017) noticed that organic amendments (straw and straw-derived biochar) with biocides combination improve soil structure in Shajiang black soil in China by promoting fungal abundance as correlation analysis showed mean weight diameter was more related to fungi as compared to bacteria. Biochar which is globally recognized as soil amendments; when added to soil surface, it impacts soil physical properties (Blanco-Canqui, 2017). There was increase and decrease in saturated hydraulic conductivity in coarse and in fine-textured soils respectively after biochar application. It was also estimated that a reduction (3 to 31%) of soil bulk density and increase (14 to 64%) in porosity due to its application. Wet aggregate stability increases to the tune of 3 to 226% and available water of the order of 4 to 130% in different types of soil and land use management. Chen *et al.* (2018) observed that the hydraulic properties of sandy soil were dependent on rate of application, particle size, and pyrolysis temperature of biochar. With the increase in rate and particle size water retention under saturation, field capacity, and dry conditions was increased. Moreover, enhancement in water retention under field capacity and dry conditions and decrease the evaporation rate under dry conditions was noted as pyrolysis temperature increases but unfortunately such effect was not recorded in wet conditions. Decreased ρb (1.05 to 1.42 g cm^{-3}) in biochar treated soil than without its application (1.54 g cm^{-3}). A range of θ_s (0.40 to 0.53%) and θ_{fc} (0.18 to 0.35%) was noted across different components than without biochar application (0.35% and 0.15% respectively). Silva *et al.* (2019) inferred conservation soil management systems including additional application of 7 to 28 Mg ha^{-1} gypsum led to better productivity in coffee and maintenance of θ in the Cerrado region of Southeastern Brazil. Roussos *et al.* (2019) through principal component analysis derived that integrated farming approach enhanced the quality and yield in Clementine mandarin along with soil physicochemical properties; of course organically produced fruits were rich in antioxidants and are environmentally safe. All such theories showed the response of soil management across soil types influence the soil hydraulic properties and were linked to productivity of various fruit crops.

Influence of tillage on soil hydraulic properties

Tillage is an important cultural operation practiced in the orchards to control weeds and pulverize the soil for better aeration. However, it has its own benefits and negative impacts. Tillage induced operations mostly destroy the structure aggregates; zero tillage or no tilled soil is thus preferred for better soil management or precision farming. However, if the plantations were lasting for over decades or several decades, there is a probability of getting the soil compacted. Under such compaction condition, ρ_d is higher resulting in lower WHC, K_s and other properties (Table 3). Mean weight diameter (MWD) and Geometric mean weight (GMW) values were also lower under tilled condition as compared to zero tilled or no tilled or minimum tillage condition. Sometimes raised bed system or furrow based system was adopted to enhance the input use efficiency. Pini *et al.* (1999) observed total soil porosity, size distribution and morphology of pores, and available water in agroforestry trial of common walnut in volcanic soil in central Italy. Experimental results from 17 grassed-down apple orchards with alley and tree line areas from organic or biological, conventional and integrated system in New Zealand showed significantly lower ρ_d and higher infiltration rate in tree line than alley in all orchards due to soil compaction by orchard vehicles in the alley (Goh *et al.*, 2001). Materechera and Gaobope (2007) suggested for proper tillage in order to enhance the productivity of the soils as subsoil compaction in the orchard and vegetable fields and shallow compaction in the vineyard. Seasonal variation in total porosity was observed with dimensional classes of pores >50 µm in systems of clean cultivation,

Table 3. Effect of tillage components on soil hydraulic properties

Soil type	Country	Fruit orchard	Changes in hydraulic properties found	Tillage components involved	Reference
Clay loam soil (Orthic Melanic Brunisol)	Canada	Dwarf apple	Aggregate stability, bulk density, temperature, water content and productivity	Minimum tillage with cultivation, composted manure, straw mulch, grass cover , cover crops and geotextile	Walsh *et al.* (1996)
Clayey	Navsari, Gujarat	Sapota, Mango, Oil Palm and Banana	Water soluble aggregates, SOC, ρ_d etc.	Varying tillage and management practices	Das and Ansari (2014)
-	Greece	Olive	Mechanical analysis, organic matter, spatial variation etc.	Both tillage and no-tillage	Fountas *et al*. (2011)
Sandy loam	Oregon, USA	Pear	Variance in soil properties organic matter etc.	Conventional tillage	Perry *et al*. (2010)
Chernozem-like soils, albic luvisols, erodisols	Romania	Plum and apple	Particle size distribution, bulk density, resistance to penetration etc	Conventional tillage	Paltineanu *et al*. (2003)
Silty loam	Lublin, Poland	Apple	Aggregates, SOC, water retention, ρ_d etc.	Conventional tillage	Lipiec *et al*. (2005)

polyethylene mulching along tree rows and intercropping of walnut with alfalfa. Pore size distribution (pores>20µm) was found to be higher in 0-10 cm soil depth in conventional tillage system as compared to lower in 10-20 cm soil depth under permanent sward in silty loam orchard soil of 35-year-old apple (Siczek *et al*., 2008). Becerra *et al*. (2010) inferred sub surface and surface compaction with higher ρ_d and lower total soil porosity under light and heavy traction in Almond orchard in Almería of southeast Spain. Similarly, water retention characteristics indicated that compaction in viticulture and fruit culture does not enhance run-off on loamy soils in Mediterranean areas (van Dijck and van Asch, 2002). Martins *et al.* (2011) observed no tillage with maintenance of spontaneous grass cover was the most favourable management system to increase productivity and biodiversity in Chestnut plantations of Northern Portugal, out of several tillage practices like conventional soil tillage, no tillage with permanent spontaneous herbaceous vegetation cover, no tillage with permanent rainfed seeded pasture cover and as no tillage + pasture + irrigation. Sometimes in centuries old tillage management of vineyards, soils beneath vines have lost their active upper horizon. Intensity of soil use also determines the changes in soil characteristics; increase in SOC content (from 0.2 to 0.6%), WHC (from 0.2 to 0.3 g H_2O per g soil) and aggregate stability (from 4 to 33 drop impacts) as it declines as observed by Acín Carrera *et al*. (2013). Based on experimentation with six tillage practices in non-irrigated apple orchard in China, Liu *et al*. (2013) inferred that subsoil tillage with straw mulching, plow tillage with mulching and no tillage with mulching had significant effect on the soil porosity, θs, water-holding capacity. Wide range of soil physical quality indicators were evaluated in an Almond orchard planted in clay soil after 30 years of cultivation and with 13 indicators it was concluded that good soil physical quality contributed by 77% in no-tillage and 46% with surface tillage in Italy (Castellini *et al*., 2013). No-tillage with chemical weed control is the best for obtaining greater yield. Das and Ansari (2014) recorded significantly higher MWD in the following order: sapota (1.61 mm) > mango (1.59 mm) > oil palm (1.43 mm)> banana (1.12 mm). Adesanya *et al*. (2016) recorded soil application of solid pig manure led to decrease ρ_d, higher θs and K_s in Orthic Black Chernozem in Manitoba, Canada. Montanaro *et al*. (2017) in a detailed study documented the ecosystem services, soil processes and socioeconomic security provided by the fruit tree peach, apricot, olive and vineyards. Implementation of conservation technologies via adoption of cover crops, retention of pruning residues, tillage/no-tillage, mineral/organic fertilization has tremendous impacts on the pivotal role of soil water and nutrient storage, SOC stocks, soil aggregates, erodibility, soil stability, and above-ground biodiversity. Some groundcover treatments with tillage had little impact on ρ_d, soil porosity and surface SOC content and it was inferred that for sustainable management practice in apple orchard in northern China, cover crops are needed (Ping *et al*., 2018). Hence, variable production system may be concluded due to tillage components.

Land use option to impact soil hydraulic properties

Dynamic changes in K_s and other hydraulic properties are related to the land use history and their management. Jhum cultivation in hilly areas, soil erosion control measures benefitted the farming community by reducing the loss; its quality and rate at which soil and water erosions was occurring. Intervention of agronomic measures in contours and other echo-hydrological measures in watershed and mountainous areas, forest and degraded lands not only enhances the profitability of fruit farming via better economic returns but also safeguarding sustainability of the system through soil conservation. Sun *et al*. (1995) used soil amendments to improve aggregate stability in Dark Brown Chernozem in southern Alberta, Canada to reduce soil resistance to wind and water erosion. Surface application of conservation technologies in coarse textured soils in high density apple orchard had impacts on soil physical properties with improvement in water retention capacity and practice suggested for future use. Wet aggregate stability varied between 3.8 to 8.4%, ρ_d (1.08 to 1.44 kg m^{-3}) and WHC at saturation (264 to 351 g kg^{-1}) (Neilsen *et al*., 2003). Jankauskas *et al*. (2008) quantified the water erosion rates (24.2 to 87.1 m^3 ha^{-1} yr^{-1} in tillage crops) on undulating slopes in Lithuania under different land use systems. Perennial grasses grown across the undulating slope completely prevented water erosion, while erosion-preventive grass-grain crop rotations (67% grasses, 33% cereal grains) decreased soil losses (75 to 80%); grain-grass crop rotation (33% grasses and 67% cereal grains) decreased soil erosion rates (23 to 24%). percentage of clay-silt and clay fractions of arable soil horizons increased, while the total soil porosity and moisture retention capacity decreased with increased soil erosion. It was further estimated that grass-grain crop rotations increased the water-stable soil aggregates to the tune of 11.03% and sod-forming perennial grasses increased aggregate stability (9.86%). She *et al*. (2010) suggested for creation of mosaic pattern through land use management to raise the moisture conservation, enhancement of erosion and runoff control. Pirastru *et al*. (2013) observed that changes in land use from forest (lower ρ_d) to grassland have unfavorable impact on soil physical and hydraulic properties. The θ_s in forested area was recorded as 0.48-0.56 cm^3 cm^{-3} than 0.41-0.45 cm^3 cm^{-3} in grassed soil; with higher K_s (455 and 280 mm h^{-1}) in forested area as compared to grassland (280 and 150 mm h^{-1}). Gómez *et al*. (2014) in detailed study indicated the average rate of sediment delivery to streams @ 16.1 t ha^{-1} $year^{-1}$ and it may go up to 52 t ha^{-1} $year^{-1}$ with rainfall greater than average annual rainfall. the role of soil conservation in gully and rill erosion should be addressed with care as it contributes significant variability in soil hydraulic properties and θ. Rathore *et al*. (2013) recommended that in mango stand with selective intercrops up to 15 years of age of mango plantation for good economic viability without deteriorating soil properties. Based on different soil types, recorded significant differences in the soil productivity indexes (0.12 to 0.85 and averaged 0.47). Holmes *et al*. (2015)

estimated SCS on an average 174.9 ± 3 t C ha^{-1} to 1 m depth from more than sixty kiwifruit orchards throughout New Zealand. Futher, difference between wine grape vineyards grown on shallow, stony alluvial soils and adjacent pasture SCS of nearly 16 t ha^{-1} was determined. For sustainable management of tree-cropping systems, fractal dimension (D_m) of soil particle size distribution and their relationships with soil bulk density, porosity, soil organic matter were investigated in five types of tree-cropping systems; D_m values ranged from 2.7318 to 2.8062, positively correlated to clay and silt contents, but negatively related to sand contents. Also a closer relationship was found between D_m and soil bulk density, non-capillary porosity than with capillary porosity, total porosity and SOM (Li *et al*., 2016). To avoid soil erosion, moisture conservation and getting higher productivity, intercropping with fodder *Brassica napus* found to be more appropriate than *Hemerocallis fulva* in jujube orchards planted on the hillslopes of the Loess Plateau (Ling *et al*., 2017). Naik *et al.* (2017) estimated that mango, guava and litchi orchards caused an enrichment of total soil organic carbon by 17.2, 12.6 and 11%, respectively than the control. It was further inferred that land use affects the stability and size distribution of soil aggregates through the integration of soil organic matter and other soil properties like oxides of Fe and Al (Zhao *et al*., 2017). However, in another study in Western Ghat, India Chatterjee *et al.* (2019) expressed that no significant differences were noted in SOC within the silt + clay fraction (< 53 μm) beyond 60 cm depth under Forest and other perennial agroforestry systems (Coffee + *Grevillea robusta*, Coffee + Mixed Shade trees, Tea + *Grevillea robusta*, Homegarden and native moist deciduous forest). Jordan *et al*. (2018) quantified irrigation water productivity, water-use efficiency and improvement in yields of irrigated crops, vegetable, hay and fruit trees by about 46 and 77% from Bulgan River watersheds in the arid and semi-arid regions of Mongolia. Soil architecture has immense potential on the preferential flow and soil physical properties in the Karst catchment area (Wang *et al*. 2018) with tillage lowering vertical percolation; with ρ_d varied between 1.32 to 1.57, 0.90 to 1.3 and 1.06 to 1.22 g cm^{-3} in sandy, sandy loam and clay soil respectively. Total porosity estimated as 40.74 to 46.05, 47.03 to 59.94 and 49.56 to 58.08% respectively in these soils while K_s had values of 6.34 to 7.45, 6.81 to 14.24 and 0.18 to 4.71 m d^{-1} in three types of soil. In order to reduce the surface runoff from the experimental site at Scotland, Chandler *et al*. (2018) concluded that tree species may significantly alter K_s; ungrazed Scots pine forest and ungrazed sycamore forest had K_s value of 1239 and 379 mm h^{-1} respectively. Cultivation in waste land and other treated problematic soils is reported to change the hydrological cycle. Soils with land use of forest tree had higher water repellency and low K_s (Lucas-Borja *et al*. 2019); with vegetation cover could improve the porosity and water holding capacity.

The recent analysis on soil hydraulic properties across different fruit based ecosystem involving various management system showed variations in these properties and also suggested for better management practices to improve the soil condition. Knowledge shearing across the stakeholders/farming community should be given priority through extension services for real time based soil quality and quantity analysis, survey and feedback, and also face to face counseling so that soils across globe can be well managed (Bruyn, 2019; Imhof *et al*., 2019).

References

Abd Rashid, N.S., Askari, M., Tanaka, T., Simunek, J., van Genuchten, M.T. 2015. Inverse estimation of soil hydraulic properties under oil palm trees. *Geoderma* **241-242**: 306-312.

Acín Carrera, M., José Marques, M., Carral, P., Álvarez, A.M., López, C., Martín López, B. and González, J.A. 2013. Impacts of land use intensity on soil organic carbon content, soil structure and water holding capacity. *Soil Use and Management* **29**(4): 547-556.

Adak, T., Kumar, K. and Singh, V.K. 2016. Variations in soil physical properties, distribution and storage of micronutrients in soil as influenced by high density mango (*Mangifera indica* L.) plantations. *Journal of Soil and Water Conservation* **15**(1): 75-86.

Adak, T., Singh, V.K., Kumar, K., Singh, Vinod Kumar and Singh, A.K. 2014. Assessment of pore water conductivity in different fertigation regimes in Dashehari Mango orchard. In: *Proceedings of International symposium on "Innovations in Horticulture for Nutritional Security, Conserving Biodiversity and Poverty Alleviation*" held during October 16-18, 2014 at BBAU, Lucknow, India. pp 108-109.

Adak, T., Singha, A., Kumar, K. and Singh, Vinod Kumar. 2017. Soil indicators as a tool to assess changes in soil properties in guava orchard ecosystem. *Indian Journal of Soil Conservation* **45**(1): 78-88.

Adesanya, T., Akinremi, O. and Zvomuya, F. 2016. Physical properties of an Orthic Black Chernozem after 5 years of liquid and solid pig manure application to annual and perennial crops. *Canadian Journal of Soil Science* **96**: 145-153.

Adesodun, J.K., Mbagwu, J.S.C. and Oti, N. 2005. Distribution of carbon, nitrogen and phosphorus in water-stable aggregates of an organic waste amended Ultisol in southern Nigeria. *Bioresource Technology* **96**(4): 509-516.

Albiach, R., Canet, R., Pomares, F. and Ingelmo, F. 2001.Organic matter components, aggregate stability and biological activity in a horticultural soil fertilized with different rates of two sewage sludges during ten years. *Bioresource Technology* **77**(2): 109-114.

Annabi, M., Bissonnais, Y. Le., Villio-Poitrenaud, M. Le. and Houot, S. 2011. Improvement of soil aggregate stability by repeated applications of organic amendments to a cultivated silty loam soil. *Agriculture, Ecosystems and Environment* **144**(1): 382-389.

Arancon, N.Q., Edwards C.A., Bierman P., Welch, C., Metzger, J.D., 2004. The influence of vermicompost applications to strawberries: Part 1. Effects on growth and yield. *Bioresource Technology* **93**:145-153.

Aranda, V., Ayora-Ca˜nada, M.J., Domínguez-Vidal, A., Martín-García, J.M., Calero, J., Delgado, R., Verdejo, T. and González-Vila, F.J. 2011. Effect of soil type and management (organic vs conventional) on soil organic matter quality in olive groves in a semi-arid environment in Sierra Mágina Natural Park (S. Spain). *Geoderma* **164**:54-63.

Asghari, S., Abbasi, F. and Neyshabouri, M.R. 2011. Effects of soil conditioners on physical quality and bromide transport properties in a sandy loam soil. *Biosystems Engineering* **109**(1): 90-97.

Bamberg, A.L., Cornelis, W. M., Timm, L. C., Gabriels, D., Pauletto, E.A. and Pinto, L. F. S. 2011. Temporal changes of soil physical and hydraulic properties in strawberry fields. *Soil Use and Management* **27**(3): 385-394.

Basile, B., Marsal, J., Solari, L.I., Tyree, M.T., Bryla, D.R. and DeJong, T.M. 2003. Hydraulic conductance of peach trees grafted on rootstocks with differing size-controlling potential. *Journal of Horticultural Science and Biotechnology* **78**:768-774.

Becerra, A.T., Botta, G.F., Bravo, X. L., Tourn, M., Melcon, F.B., Vazquez, J., Rivero, D., Linares, P. and Nardon, G. 2010. Soil compaction distribution under tractor traffic in almond (*Prunus amigdalus* L.) orchard in Almería Espaρa. *Soil and Tillage Research* **107**(1): 49-56.

Blanco-Canqui, H. 2017. Biochar and Soil Physical Properties. *Soil Science Society of American Journal* **81**: 687-711.

Bruyn, L.L.A. 2019. Learning opportunities: Understanding farmers' soil testing practice through workshop activities to improve extension support for soil health management. *Soil Use and Management* **35**: 128-140.

Castellini, M., Niedda, M., Pirastru, M. and Ventrella, D. 2014. Temporal changes of soil physical quality under two residue management systems, *Soil Use and Management* **30**(3): 423-434.

Castellini, M., Pirastru, M., Niedda, M. and Ventrella, D. 2013. Comparing physical quality of tilled and no-tilled soils in an almond orchard in southern Italy. *Italian Journal of Agronomy* **8**:e20: 149-157.

Chandler, K.R., Stevens, C.J., Binley, A. and Keith, A.M. 2018. Influence of tree species and forest land use on soil hydraulic conductivity and implications for surface runoff generation. *Geoderma* **310**:120-127.

Chatterjee, N., Nair, P.K.R., Nair, V.D., Viswanath, S. and Bhattacharjee, A. 2019. Depth-wise distribution of soil-carbon stock in aggregate-sized fractions under shaded-perennial agroforestry systems in the Western Ghats of Karnataka, India. *Agroforestry Systems*. https://doi.org/10.1007/s10457-019-00399-z.

Chen, C., R. Wang, J. Shang, K. Liu, M.K. Irshad, K. Hu, and E. Arthur. 2018. Effect of biochar application on hydraulic properties of sandy soil under dry and wet conditions. *Vadose Zone J.* **17**:180101. doi:10.2136/vzj2018.05.0101.

Das, A. and Ansari, M.Z. 2014. Organic Carbon, Bulk Density and Aggregate Stability of a Vertisol as Affected by Varying Plantations /Vegetation Covers in South Gujarat. *Journal of Agricultural Physics* **14**(2): 213-218.

Dec, D and Dörner, J. 2014. Spatial variability of the hydraulic properties of a drip irrigated andisol under blueberries. *Journal of Soil Science and Plant Nutrition* **14**(3), 589-601.

Deurer, M., Sivakumaran, S., Ralle, S., Vogeler, I., McIvor, I., Clothier, B., Green, S. and Bachmann, J. 2008. A New Method to Quantify the Impact of Soil Carbon Management on Biophysical Soil Properties: The Example of Two Apple Orchard Systems in New Zealand. *Journal of Environmental Quality* **37**(3): *915-924.*

Egea, G., González-Real, M.M., Baille, A., Nortes, P.A., Conesa, M.R., Ruiz-Salleres, I. 2012. Effects of water stress on irradiance acclimation of leaf traits in almond trees. *Tree Physiology* **32**(4): 450-463.

El-Shazly, S.M., Mustafa, N.S. and El-Berry, I.M. 2014. Evaluation of some fig cultivars grown under water stress conditions in newly reclaimed soils. *Middle-East Journal of Scientific Research* **21**(8): 1167-1179. DOI: 10.5829/idosi.mejsr.2014.21.08.21680.

Farag, A.A., Eltaweel, A.A., Abd-Elrahman, S.H., Ali, A.A. and Ahmed, M.S.M. 2017. Irrigation Regime and Soil Conditioner to Improve Soil Properties and Pomegranate Production in Newly Reclaimed Sandy Soil. *Asian Journal of Soil Science and Plant Nutrition* **1**(2): 1-18.

Fernández, J.E., Durán, P.J., Palomo, M.J., Diaz-Espejo, A., Chamorro, V. and Girón, I.F. 2006. Calibration of sap flow estimated by the compensation heat pulse method in olive, plum and orange trees: relationships with xylem anatomy. *Tree Physiology* **26**(6): 719-728.

Foshee, W.G., Raper, D.G., Goff, W.D., Patterson, M.G. 1997. Orchard floor practices affect soil compaction around young pecan trees. *HortScience* **32**: 871-873.

Fountas, S., Aggelopoulou, K., Bouloulis, C., Nanos, G.D., Wulfsohn, D., Gemtos, T.A., Paraskevopoulos, A. and Galanis, M. 2011. Site-specific management in an olive tree plantation. *Precision Agric* **12**: 179-195.

Goh, K.M., Pearson, D.R. and Daly, M.J. 2001. Effects of Apple Orchard Production Systems on Some Important Soil Physical, Chemical and Biological Quality Parameters. *Biological Agriculture & Horticulture* **18(3)**: 269-292.

Gómez, J.A., Vanwalleghem, T., Hoces, A.D. and Taguas, E.V. 2014. Hydrological and erosive response of a small catchment under olive cultivation in a vertic *soil* during a five-year period: Implications for sustainability. *Agriculture, Ecosystems & Environment* **188**: 229-244.

González, M., Gomez, E., Comese, R., Quesada, M. and Conti, M. 2010. Influence of organic amendments on soil quality potential indicators in an urban horticultural system. *Bioresource Technology* **101**(22): 8897-8901.

Gonzalez, R.F. and Cooperband L.R. 2002. Compost Effects on Soil Physical Properties and Field Nursery Production. *Compost Science & Utilization* **10**(3): 226-237.

Gucci, R., Caruso, G., Bertolla, C., Urbani, S., Taticchi, A., Esposto, S., Servili, M., Sifola, M. I., Pellegrini, S., Pagliai, M. and Vignozzi, N. 2012. Changes of soil properties and tree performance induced by soil management in a high-density olive orchard. *European Journal of Agronomy* **41**: 18-27.

Hannam, K.D., Neilsen, G.H., Forge, T.A., Neilsen, D., Losso, I., Jones, M.D., Nichol, C. and Fentabil, M.M. 2016. Irrigation practices, nutrient applications, and mulches affect soil nutrient dynamics in a young Merlot (*Vitis vinifera* L.) vineyard. *Canadian Journal of Soil Science* **96**: 23-36.

Haynes, R.J. 1980-81. Effects of soil management practices on soil physical properties, earthworm population and tree root distribution in a commercial apple *orchard. Soil and Tillage Research* **1**: 269-280.

Holmes, A., Müller, K., Clothier, B. and Deurer, M. 2015. Carbon Sequestration in Kiwifruit Orchard Soils at Depth to Mitigate Carbon Emissions. *Communications in Soil Science and Plant Analysis* **46**: 122-136. https://doi.org/10.1080/00103624.2014.988583.

Imhof, M.P., Heemskerk, G.E. and Cox, M.T. 2019. Soil information management and knowledge sharing in Victoria, Australia-user perspectives. *Soil Use and Management* **35**:39-51.

Jankauskas, B., Jankauskienë, G. and Fullen, M.A. 2008. Soil erosion and changes in the physical properties of Lithuanian Eutric Albeluvisols under different land use systems. *Acta Agriculturae Scandinavica, Section B - Soil & Plant Science* **58**(1): 66-76.

Jara, J., Holzapfel, E.A., Billib, M., Arumi, J.L., Lagos, O. and Rivera, D. 2017. Effect of water application on wine quality and yield in 'Carménθre' under the presence of a shallow water table in Central Chile. *Chilean Journal of Agricultural Research* **77**(2): 171-179.

Jordan, G., Goenster-Jordan, S., Lamparter, G.J., Ulziisuren B., Soninkishig, N., Schlecht, E. and Buerkert, A. 2018. Water use in agro-pastoral livelihood systems within the Bulgan River watershed of the Altay Mountains, Western Mongolia. *Agriculture, Ecosystems and Environment* **251**: 180-193.

Konopatzki, M.R.S., Souza, E.G., Nóbrega, L.H.P., Bazzi, C.L. and Rocha, D.M. 2016. Spatial variability of chemical attributes of the soil, plant and yield in a pear orchard. *Journal of Plant Nutrition* **39**(3): 323-336.

Kroener, E., Holz, M., Zarebanadkouki, M., Ahmed, M. and Carminati, A. 2018. Effects of mucilage on rhizosphere hydraulic functions depend on soil particle size. *Vadose Zone J.* **17**:170056. doi:10.2136/vzj2017.03.0056.

Lechaudel, M., Vercambre, G., Lescourret, F., Normand, F. and Génard, M. 2007. An analysis of elastic and plastic fruit growth of mango in response to various assimilate supplies. *Tree Physiology* **27**(2): 219-230.

Li, T., He, B., Zhang, Y., Tian, J., He, X., Yao, Y. and Chen, X. 2016. Fractal analysis of soil physical and chemical properties in five tree-cropping systems in southwestern China. *Agroforestry Systems* **90**(3): 457-468.

Ling, Q., Gao, X., Zhao, X., Huang, J., Li, H., Li, L., Sun, W. and Wu, P. 2017. Soil water effects of agroforestry in rainfed jujube (*Ziziphus jujube* Mill.) orchards on loess hillslopes in Northwest China. *Agriculture, Ecosystems and Environment* **247**: 343-351.

Lipiec, J., Witkowska-Walczak, B. and Nosalewicz, A. 2005. Long-term orchard management effects on some soil hydraulic and biological properties. *Geophysical Research Abstracts* **7**: 02609.

Liu, Y., Gao, M., Wu, W., Tanveer, SK., Wen, X. and Liao, Y. 2013. The effects of conservation tillage practices on the soil water-holding capacity of a non-irrigated apple orchard in the Loess Plateau, China. *Soil and Tillage Research* **130**: 7-12.

Lu, P., Müller, W.J. and Chacko, E.K. 2000. Spatial variations in xylem sap flux density in the trunk of orchard-grown, mature mango trees under changing soil water conditions. *Tree Physiology* **20**(10): 683-692.

Lucas-Borja, M.E., Zema, D.A., Plaza-Álvarez, P.A., Zupanc,V., Baartman, J., Sagra, J., González-Romero, J., Moya, D. and de las Heras, J. 2019. Effects of different land uses (Abandoned Farmland, Intensive Agriculture and Forest) on soil hydrological properties in southern Spain. *Water* **11**: 503. doi:10.3390/w11030503.

Magesan, G.N., Williamson, J.C., Yeates, G.W. and RhLloyd-Jones A. 2000. Wastewater C:N ratio effects on soil hydraulic conductivity and potential mechanisms for recovery. *Bioresource Technology* **71**(1): 21-27.

Marsal, J. and Girona, J. 1997. Effects of water stress cycles on turgor maintenance processes in pear leaves (*Pyrus communis*). *Tree Physiology* **17**(5): 327-333.

Martins, A., Marques, G., Borges, O., Portela, E., Lousada, J., Raimundo, F. and Madeira, M. 2011. Management of chestnut plantations for a multifunctional land use under Mediterranean conditions: effects on productivity and sustainability. *Agroforestry Systems* **81**: 175-189.

Martins, A., Raimundo, F., Borges, O., Linhares, I., Sousa, V., Coutinho, J., Gomes- Laranjo J and Madeira, M. 2010. Effects of soil management practices and irrigation on plant water relations and productivity of chestnut stands under Mediterranean conditions. *Plant and Soil* **327**: 57-70.

Materechera, S.A. and Gaobope, K. 2007. Soil compaction by tractor tillage in horticultural fields at Molelwane research farm, Mafikeng, North West Province. *South African Journal of Plant and Soil* **24**(1): 58-61.

Merwin, I.A., Stiles, W.C. and van Es, H.M. 1994. Orchard groundcover management impacts on soil physical properties. *Journal of the American Society for Horticultural Sciences* **119**(2): 216-222.

Montanaro, G., Xiloyannis, C., Nuzzo,V. and Dichio, B. 2017. Orchard management, soil organic carbon and ecosystem services in Mediterranean fruit tree crops. *Scientia Horticulturae* **217**: 92-101.

Naganna, S.R., Deka, P.C., Sudheer Ch., Hansen, W.F. 2017. Factors influencing streambed hydraulic conductivity and their implications on stream-aquifer interaction: a conceptual review. *Environmental Science and Pollution Research* **24**(32): 24765-24789.

Naik, S.K., Maurya, S. and Bhatt, B.P. 2017. Soil organic carbon stocks and fractions in different orchards of eastern plateau and hill region of India. *Agroforestry Systems* **91**(3): 541-552.

Naor, A., Schneider, D., Ben-Gal, A., Zipori, I., Dag, A., Kerem, Z., Birger, R., Peres M. and Gal Y. 2013. The effects of crop load and irrigation rate in the oil accumulation stage on oil yield and water relations of 'Koroneiki' olives. *Irrigation Science* **31**(4):781-791.

Nardini, A., Gascó, A., Raimondo, F., Gortan, E., Lo Gullo, M.A., Caruso, T. and Salleo, S. 2006. Is rootstock-induced dwarfing in olive an effect of reduced plant hydraulic efficiency? *Tree Physiology* **26** (9): 1137-1144.

Neilsen, G.H., Hogue, E.J., Forge, T. and Neilsen, D. 2003. Surface application of mulches and biosolids affect orchard soil properties after 7 years. *Canadian Journal of Soil Science* **83**: 131-137.

Noitsakis, B., Chouzouri, A., Papa, L. and Patakas, A. 2016. Pomegranate physiological responses to partial root drying under field conditions. *Emirates Journal of Food and Agriculture* **28**(6): 410-414.

Olsson, K.A. and Rose, C.W. 1988. Patterns of water withdrawal beneath an irrigated peach orchard on a red-brown earth. *Irrigation Science* **9**(2): 89-104.

Oyarzún, R., Stöckle, C. and Whiting, M. 2010. Analysis of hydraulic conductance components in field grown, mature sweet cherry trees. *Chilean Journal of Agricultural Research* **70**(1): 58-66.

Paltineanu, C., Chitu, E., Tanasescu, N., Moldoveanu, D. and Prefac, Z. 2003. Relationships between some soil properties and growth indexes in plum and apple trees within the hilly regions of Romania. *International Agrophysics* 17.

Paltineanu, C., Septar, L., Gavat, C., Chitu, E., Oprita, A., Moale, C., Calciu, I., Vizitiu, O. and Lamureanu, G. 2016. Characterising root density of peach trees in a semi-arid Chernozemto increase plant density. *International Agrophysics* **30**: 67-74.

Paltineanu, C., Tanasescu, N. and Chitu. E. 2016. Pattern of soil physical properties in intensive plum and apple *orchards* on medium and coarse textured soils. *Soil and Tillage Research* **163**: 80-88.

Paudel, I., Cohen, S., Shaviv, A., Bar-Tal, A., Bernstein, N., Heuer, B. and Ephrath, J. 2016. Impact of treated wastewater on growth, respiration and hydraulic conductivity of citrus root systems in light and heavy soils. *Tree Physiology* **36**(6): 770-785.

Perry, E.M., Dezzani, R.J., Seavert, C.F. and Pierce, F.J. 2010. Spatial variation in tree characteristics and yield in a pear orchard. *Precision Agric.* **11**:42-60.

Ping, X.Y., Wang, T.M., Yao, C.Y. and Lu, X.S. 2018. Impact of floor management practices on the growth of groundcover species and soil properties in an apple orchard in northern China. *Biological Rhythm Research* **49**(4): 597-609.

Pini, R., Paris, P., Guidi, G.V. and Pisanelli, A.1999. Soil physical characteristics and understory management in a walnut (*Juglans regia* L.) plantation in central Italy. *Agroforestry Systems* **46**(1): 95-105.

Pirastru, M., Castellini, M., Giadrossich, F. and Niedda, M. 2013. Comparing the hydraulic properties of forested and grassed soils on an experimental hillslope in a Mediterranean environment. *Procedia Environmental Sciences* **19**: 341-350.

Rahman, M.T., Zhu, Q.H., Zhang, Z.B., Zhou, H. and Peng, X. 2017. The roles of organic amendments and microbial community in the improvement of soil structure of a Vertisol. *Applied Soil Ecology* **111**: 84-93.

Ramos, M.E., Robles, A.B., Sa´nchez-Navarro, A., Gonza´lez-Rebollar, J.L. 2011. Soil responses to different management practices in rainfed orchards in semiarid environments. *Soil and Tillage Research* **112**: 85-91.

Rathore, A.C., Saroj, P.L., Lal, H., Sharma, N.K., Jayaprakash, J., Chaturvedi, O.P., Raizada, A., Tomar, J.M.S. and Dogra, P. 2013. Performance of mango based agri-horticultural models under rainfed situation of Western Himalaya, India. *Agroforestry Systems* **87**(6): 1389-1404.

Reynolds, W.D., Drury, C.F., Tan, C.S., Fox, C.A. and Yang, X.M. 2009. Use of indicators and pore volume-function characteristics to quantify soil physical quality. *Geoderma* **152**(3-4): 252-263.

Roussos, P.A., Flessoura, I., Petropoulos, F., Massas I., Tsafouros, A., Ntanos, E. and Denaxa, N.K. 2019. Soil physicochemical properties, tree nutrient status, physical, organoleptic and phytochemical characteristics and antioxidant capacity of clementine mandarin (*Citrus clementine* cv. SRA63) juice under integrated and organic farming. *Scientia Horticulturae* **250**: 414-420.

Shahab, H., Emami, H. and Karimi, A. 2013. Pore size distribution as a soil physical quality index for agricultural and pasture soils in northeastern Iran. *Pedosphere* **23**: 312-20.

She, D.L., Shao, M.A., Timm, L.C., Sentís, I.P., Reichardt, K. and Yu, S.E. 2010. Impacts of land-use pattern on soil water-content variability on the Loess Plateau of China. *Acta Agriculturae Scandinavica, Section B - Soil & Plant Science* **60**(4): 369-380.

Siczek, A., Kotowska, U., Lipiec, J. and Nosalewicz, A. 2008. Leaching of potassium, magnesium, manganese and iron in relation to porosity of tilled and orchard loamy soil. *Acta Agriculturae Scandinavica, Section B - Soil & Plant Science* **58**(1): 60-65.

Silva, B.M., Oliveira, G.C., Serafim, M.E., Silva, É.A., Guimarães, P.T.G., Batista Melo, L.B., Norton, L.D. and Curi, N. 2019. Soil moisture associated with least limiting water range, leaf water potential, initial growth and yield of coffee as affected by soil management system. *Soil and Tillage Research* **189**: 36-43.

Sperling, O., Shapira, O., Cohen, S., Tripler, E., Schwartz, A. and Lazarovitch, N. 2012. Estimating sap flux densities in date palm trees using the heat dissipation method and weighing lysimeters. *Tree Physiology* **32**(9): 1171-1178.

Sun, H., Lamey, F.J. and Bullock, M.S. 1995. Soil amendments and water-stable aggregation of a desurfaced Dark Brown Chernozem. *Canadian Journal of Soil Science* **75**: 319-325.

Tardaguila, J., Baluja J., Arpon L., Balda P.,Oliveira, M. 2011. Variations of soil properties affect the vegetative growth and yield components of ''Tempranillo'' grapevines. *Precision Agriculture* **12**: 762-773.

Tisdall, J.M. and Hodgson, A.S. 1990. Ridge tillage in Australia: a review. *Soil and Tillage Research* **18**(2-3): 127-144.

Tisdall, J.M., Olsson, K.A. and Willoughby, P. 1984. Soil structural management and production in a non-cultivated peach *orchard. Soil and Tillage Research* **4**(2): 165-174.

Tiwari, K.N., Kumar, M., Santosh, D.T., Singh, V.K., Maji, M.K., and Karan, A.K. 2014. Influence of Drip Irrigation and Plastic Mulch on Yield of Sapota (Achraszapota) and Soil Nutrients. *Irrigation and Drainage Systems Engineering* **3**: 116. doi:10.4172/2168-9768.1000116.

van Dijck, S.J.E. and van Asch, Th. W.J. 2002. Compaction of loamy soils due to tractor traffic in vineyards and *orchards* and its effect on infiltration in southern France. *Soil and Tillage Research* **63**(3-4): 141-153.

Vogeler, I., Cichota, R., Sivakumaran, S., Deurer, M. and McIvor, I. 2006. Soil assessment of apple orchards under conventional and organic management. *Australian Journal of Soil Research* **44**(8): 745-752.

Walsh, B.D., Salmins, S., Buszard, D.J. and MacKezie, A.F. 1996. Impact of soil management systems on organic dwarf apple orchards and soil aggregate stability, bulk density, temperature and water content. *Canadian Journal of Soil Science* **76**: 203-209.

Wang, F., Chen, H., Lian, J., Fu, Z. and Nie, Y. 2018. Preferential flow in different soil architectures of a small Karst catchment. *Vadose Zone J.* **17**: 180107. doi:10.2136/vzj2018.05.0107.

Xingwu, D., Li, R., Guangli, Z., Jinming, H. and Haiyan, F. 2015. Soil productivity in the Yunnan province: Spatial distribution and sustainable utilization. *Soil and Tillage Research* **147**: 10-19.

Yang, Q., Zhang, F., Li, F. and Liu, X. 2013. Hydraulic conductivity and water-use efficiency of young pear tree under alternate drip irrigation. *Agricultural Water Management* **119**: 80-88.

Yuge, K., Yasunaga, E., Fukuda, S., Spreer, W., Sardsud, V. and Pattanopo, W. 2013. Evaluation of Soil Water Management Difference in Mango Orchards between Thailand and Japan. *American Journal of Plant Sciences* **4**: 182-187.

Zeng, Ch., Wang, Q., Zhang, F. and Zhang, J. 2013. Temporal changes in soil hydraulic conductivity with different soil types and irrigation methods. *Geoderma* **193-194**: 290-299.

Zhao, J., Chen, S., Hu, R. and Li, Y. 2017. Aggregate stability and size distribution of red soils under different land uses integrally regulated by soil organic matter, and iron and aluminum oxides. *Soil and Tillage Research* **167**: 73-79.

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