Vol. 19, No. 1, pp. 35-45 (2019)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Review Article

Advanced Knowledge on Soil and Water Conservation Measures in Fruit Orchards

TARUN ADAK*, G. PANDEY AND S. RAJAN

ICAR- Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow-226101, Uttar Pradesh

ABSTRACT

Water is precious commodity and advanced knowledge on soil and water conservation in orchard growing is utmost requirement. Associated traditional knowledge in conjunction with advanced practices enhanced the scope of conservation strategies. Water conservation technologies to reduce the soil erosion runoff, sediment and nutrient loss in sloppy or other land use systems along with watershed development programme are needs to be adopted. Climate change issues are ever concerning as the way it impacts on water bodies and rainfall patterns etc. Rainwater harvesting, rooftop water conservation or in soil ground not only enhanced the chances of ground water recharge but also of pond recharge capacity. Water quality is therefore most important issue for human consumption as well as fruit production. Hence its management is prerequisite for long-term sustainable survival of civilians. The present study dealt with advanced knowledge with soil water conservation for improved fruit production.

Key words: Soil and water conservation, Traditional and advanced methodology, Water harvesting, Water quality, Climate change, Policy frameworks

Soil and water conservation process is the order of the day as they are precious in this earth for supporting lives of human, animal, fish, trees and insects etc. Our traditional methods for conservation of soil and water across different land use systems are one of the finest important technologies since past civilization era. Considering the socio-economic condition, soil and water conservation strategies are utmost needed for providing food, fodder and fuel. Simultaneously, the century old human civilization had its own way of handling the water bodies, recharge cycling and its further use. In order to provide safe way for disposal of untreated waste water and potable clean drinking water for ever increasing human and animal population, thriving for fish culture, fruit production, modern day technologies are being implemented which further needs to succeed the movement on water conservation. Perception and awareness of farmers are essential for soil and water conservation in orchards (Adak *et al.,* 2017). Policy framework should be developed and implemented in different terrain for soil and water conservation along with fruit production. Countries across the world were well aware of hazardous impact of soil erosion, water and nutrient losses as well (Roointan *et al.,* 2018; Rawat *et al.,* 2017); precisely developing towards better fruit juice, nutrient rich fruit production even in sloppy, waste, degraded and stony/gravely land ecosystems (Bennie and Hensley, 2004; Atucha *et al.,* 2013). Even, the climate change impacts have a say on the irrigation sector and water balance mechanisms (Marshall *et al.,* 2015; Qureshi *et al.,* 2013). Ganjegunte and Clark

*Corresponding author,
Email: tarunadak@gmail.com

(2017) experimentally proved for conservation of considerable amount of freshwater by precise irrigation scheduling based on real-time soil moisture without influencing pecan nut yield and soil salinity in Texas, USA. Jain (2019) analyzed and suggested for water resource management in India. Fernandez (2017) motivated for erosion control in New Zealand as economic benefits are associated with it. However, sometimes farmers' vested interest in his own lands improved the efficiency of resource management but rented lands also needs optimum care (Gao *et al.,* 2018; Adak *et al.,* 2018). Irrigation quality is also priority areas for reusing the saline or sodic water for increasing water availability and use. All these associated knowledge certainly enhanced the perception of policy planners/stakeholders which further benefit for the energy output of lands and better economic livelihood as suggested by Keesstra *et al.* (2018). Thus, integrated approach is foremost important and prerequisite for successful conservation of soil and water on the earth.

Traditional and advanced methods on soil and water conservation

Fruit productivity and biodiversity is interdependent on a range of issue concerning resource management (Fig. 1). The problem of water conservation started with the increasing gap in demand-supply chain. Ground water is depleting over the years and the rate of recharge is much lower and slower than the rate of discharge/uptake. With the increasing water demand towards modern industrialization, agriculture-horticulture along with associated sector like human, livestock and pisciculture, the need for water conservation and its efficient use becomes much more relevant in present day scenario. Traditional methods which comprised of creation, construction and maintenance of ponds, tank, wells, jalkund, pitcher etc. and other earthen or cemented structures were innovated for indigenous people. All these structures were efficiently reserves rain/ ground water for efficient use. Giordano *et al.* (2015) expressed the necessity for protection policy of ground water by the farmers. Generally for fruit crops like mango and guava, basin irrigation or flooding the entire fields are the common practice observed (Fig. 2). Canal irrigation supply is still used to provide water requirement of the crops. However, all these methods reduce the efficient water usage and water loss is huge. Das *et al.* (2012) opined the indigenous methods for natural resource conservation in hilly areas. Modern measures include micro-irrigation like sprinkler, drip fertigation for increasing the water and nutrient use efficiency as well. It was observed that drip fertigation in mango is an efficient way of water conservation with enhanced heat and water use efficiency (Adak *et al.,* 2016). The economic benefits of drip fertigation techniques needed to be disseminated among the growers (Fig. 3). Enthusiastic participation of farmers is the foremost requirement to educate for such conservation measures to become fruitful (Czap *et al.,* 2019). Knowledge on advanced system helped in attaining enhanced water productivity even in arid ecosystem. Although sometimes climate change impacts on water use, yet precise management are needed (Valverde *et al.,* 2015). Table 1 depicts the water conservation measures on fruit crops across soil and ecology.

Fig. 1. Mango production under good soil and water management system

Soil erosion, runoff, and sediment losses across terrains and watershed

The frequency and intensity of rainfall determines the extent of soil and water loss from orchards. Intense rainfall for over a long hours or days has contributing more runoff loss than low

Fig. 2. Traditional methods of flooding in mango and guava orchards

Fig. 3. Water conservation in Aonla production through drip irrigation technology

Table 1. *In-situ* water conservation effects on fruit trees across soil and ecology

Fruit crop	Measures	Impact	Reference
Strawberries	Multiplatform precision farming	Water saving (11 to 33%)	Perea *et al.* (2017)
Ladyfinger-tomato-melon system	Drip irrigation	Improvements in yield and water use efficiency	Saxena *et al.* (2016)
Jujube	Mulching of jujube branches, twigs and leaves	Reduced surface runoff and sediment yield loss	Wang *et al.,* (2015)
Nagpur mandarin	Continuous trenching, continuous bunding, and staggered trenching between	Yield improvement, conserving soil loss	Panigrahi *et al.* (2009)
Olive orchard	Barley strip cropping without tillage is best for conservation purpose under rainfed mountainous	Reduction on soil erosion and runoff, higher moisture retention	Duŕan Zuazo *et al*. (2009)
Apricot trees	Soil management like mini-catchment and perforated top soil	Improved water infiltration, saving (6-9%) and reduced runoff losses from loamy soil	Abrisqueta *et al.* (2007)

Table 2. Appraisal of soil and water conservation measures on fruit orchards under various management strategies

Orchard	Strategy	Outcomes	Reference
Mango	Regulated deficit irrigation	Higher fruit yield in post harvest stage; final fruit growth stage is sensitive to deficit irrigation	Levin *et al.* (2018)
Pistachio	Saline and non-saline irrigation water	Highest saline water had lower water use and significant variations in ET.	Jin *et al.* (2018b)
Olive	Catchment area	Low infiltration in surface soil with high permeability in sub-surface; greater soil loss.	Rodrigo-Comino *et al.* (2018)
Citrus	Irrigation with saline reclaimed water	Seasonal measurements of leaf chlorophyll content should be used as salt and water stress indicator	Romero-Trigueros *et al.* (2014)
Plum	Regulated deficit irrigation	Water saving (30%), increase in water use efficiency	Intrigliolo and Castel (2010)
Stone and Pome fruit	Adoption of sustainable irrigation practices	Redevelopment of orchard	Boland *et al.* (2006)

or moderate rainfall intensity. Infiltration to soil and percolation to ground water is a steady process and water movement follows Darcy's law. Thus, high frequency rainfall or precipitation contributed less to ground water recharge unless it is conserved *in-situ* conditions. The nutrient and sediment loss ultimately deteriorates the soil health. Steam flow through tree trunk or interception by canopy leaves improves the moisture conservation below ground in tree basins (Castro *et al.,* 2006). Construction of some barriers along the slope in contour like trenching, moon terracing, half-moon terracing, helps in improving the moisture loss control. Vegetation had tremendous impacts on the runoff-erosion control measures thereby stripe cropping, cover crops, grass cover, intercropping and various agro-forestry options needs to be practiced in strict sense both for moisture and soil conservation (Nuberg *et al.,* 1993; Keesstra *et al.,* 2016). River basins very often erode the top fertile soil and contribute to nutrient loss under flooding situation. Hence sensitization of policy planner and growers' on soil and water erosion, sediment loss across various terrains improves not only the conservation of natural resources but also of livelihood of local farmers associated with orchard growing near the vicinity areas. Fruit productions under watershed areas have immense value for nutritional security (Xu *et al.,* 2012). It has been observed that the adoption of conservation measures enhanced both profitability and soil conditions. Sensitizations among growers are very much needed for the fruitful implementation of conservation measures irrespective of land holding size, age group, socio-economic condition and educational status (Bekele and Drake, 2003). Grass mulching improved moisture retention and soil loss reduction as observed by Adekalu *et al.* (2007); similar approach was also emphasized by Podwojewski *et al.* (2011) and Moreno-Ramón *et al.* (2014) to decrease soil detachment during rainfall. Table 2 describes the appraisal of various management strategies on fruit orchards.

Rain water harvesting, river basin, reservoir and other conservation protocols

Rainwater harvesting is of top most priority for a nation to save precious water and also to meet out the thirsty of its people. This has tremendous potential for areas with low rainfall intensity and prevalent of larger duration of draught conditions. Heavy rainfall may be collected over a pond, wells or in ground tankas; construction of dams and reservoirs to store large volume of rainwater. Hence, more emphasis needs to be given on construction of tile drainage to

percolate the rainwater from ground surface to ground water. *In-situ* rainwater harvesting in fields through creation of small or large ponds for irrigation and fish farming is the need of the day. Roof top water harvesting and storage in wells also provide consumable water to feed large scale urban population. In rainfed areas, farmers must be advised to adopt the *in-situ* consumption protocol to supply lifesaving irrigation for fruit and vegetable cultivation. Banana growing entrepreneurs benefited the most through drip fertigation (Fig. 4). Siltation problem reduces the chances of volume of water to be stored in river or reservoir. Overflow river basin many a times limits water storage indicating to river linking. Brinegar and Ward (2009) suggested for amicable solution for providing basin irrigation facilities for a vast area under food production. The supply of irrigation water from water sources is an issues pertaining to the delivery, efficacy and economic viability in agri-horticulture for farmers. Zema *et al*. (2019) suggested for improving system proficiency in Southern Italy. Liu *et al.* (2012) implemented some of the water conservation measures in citrus plantations in reservoir areas in China while Panigrahi *et al.* (2017) suggested measures for citrus productivity in drought prone clayey soils in India. Motivation and enthusiastic participations of farmers and farm women are the best way for soil and water conservations in Bolivia as observed by Kessler (2007); southern Spain (Alcántara *et al.*, 2011) and Lake basin area in China (Tu *et al.,* 2018). Grassland, concrete bunds and other structures proved to be beneficial to erosion losses in delta or river basin (Lussier *et al.,* 2018). Therefore, knowledge on water management and horticultural production are prerequisite for sustainable use of precise resources (Cancela *et al.,* 2017).

Impacts of climate change on water bodies

Globally the affects of climate change on the precipitation and rainfall pattern is accepted. However, the changes in rainfall frequency and distribution pattern were observed to be greater in recent past years compared to last centuries. It was further noticed that rainfall received within the geographical location varies from year to year and even within the monsoon season (Mishra, 2019). Scattered rainfall makes it further worsen situation for precise water conservation. Draught condition reduces the fruit productivity and had serious impact on water bodies like Lake, river, canal, pond as they dried up and becomes unfavorable for utilization. Therefore global warming poses serious threat on the water bodies by making restrictions on recharges and recycling of quality water (Madhusoodhanan *et al.,* 2016). Ground water recharge impacted due to poor distribution of rainfall and increases in severe rainstorm, hailstorm and floods events which further poses threat on ocean, forest, orchards in coastal and temperate ecology. All such events lead to hydrological complications in water dynamics, water and nutrient uptake and root

Fig. 4. Water conservation in Banana production through drip irrigation technology

Fig. 5. Moisture conservation through drip irrigation technology in Bael production

physiology of fruit crops. Deficit irrigation strategy was evolved to support the moisture conservation, supply and fruit productivity (Mouron *et al.,* 2006). Demonstration of moisture conservation benefits on fruit production in hardy crop like Bael under subtropical condition was depicted (Fig. 5). Cao *et al.* (2018) observed the differential root water uptake from different soil depths and yield variations in Cherry and suggested for water regulation. Sweet *et al.* (2017) analyzed the impact of draught and expressed the concern of climatic risk on water resources for farmers. Higher temperature regimes many a times forced to change the thermal growing season of crop/tree and had many phenological implications. Such incidents were recorded in different parts of the world like, changes in growing season pattern in China (Cui *et al.,* 2019) and Canada (Qian *et al.,* 2011). It has deleterious impacts on the farm productivity and profitability of the farmers. Supplemental irrigation is needed to save life cycles of trees/crops during the draught or warmest condition; growers in rainfed areas were dependant on ground water sources for providing the lifesaving irrigation and due to scarcity of water farmers were heavily affected. Moisture conservation through mulching and drip irrigation provides the scope for growers to cherish (Fig. 6). Jin *et al.* (2018a) practiced the mulching to conserve moisture and increasing

Fig. 6. Water conservation through mulching and drip irrigation in Mango

WUE in Jujube. Bigelow and Zhang (2018) explained about climate change induced water scarcity on water rights of farmers. Adaptation strategies should be evolved to avoid fruit/crop loss and draught resiliency (Adamson *et al.,* 2017).

Water quality and associated measures for improvement

Good quality of water is the ultimate result of any indigenous soil and water conservation system. Even in advanced system also water quality plays the significant role either for drinking or through irrigation for fruit production. Refining of untreated waste water is obviously needed to use it for consumption. Industrial effluents can be treated for utilization to irrigation. Moreover, water stored in wells and ponds were often treated before human or animal consumptions. Similarly, quality of water for potable drinking water purposes from river basin or reservoir or canal, is also being free from micro-organisms. Saline or sodic laden irrigation water often poses problem of toxicity for fruit production which needs treatments (Tadayonnejad *et al.,* 2017). Hussain *et al*. (2012) recorded low chloride accumulation for salt stress impact on Citrus. Xia *et al.* (2015) evaluated the water quality of water bodies as impacted by climate change. Romero-Trigueros *et al.* (2017) observed the usefulness of saline reclaimed water for the purpose of irrigation in grapefruit and mandarin over eight years of cultivation. Quality of harvested rainwater is also needed to be tested for further betterment. Thus, water and its quality parameters including biological counts affect most on both human consumption and agricultural production. Even, harvesting of dew and storage can amicably provide life saving irrigation water to tree seedlings under desert conditions (Tomaszkiewicz *et al.,* 2017). In fact, farmers risk to practice faulty irrigation system and unaware of quality proved to be risky fruit business (Zuo *et al.,* 2015). Therefore, participatory approach is always welcome to meet out the water movement objectives (Stoate *et al.,* 2019).

Conclusion

The current analysis indicated the vast area required for conservation of soil and water. Traditional methods need to be upgraded owing to increasing pressure on water demands and use. Indigenously grown fruit crops require precise management for sustaining livelihood security of farmers. Advanced methods have beneficial impact on increasing water and nutrient use efficiency and water saving as well. Growers of arid, semi-arid and temperate regions often suffer from draught or flood. Hence, needs rain and dew water harvesting to irrigate the root zone and constructions of dams or canal or river basin for in-situ water collection are needed. Control measures should be implemented to reduce soil erosion and water loss. Farmers' participation and opinion are crucial for ground water maintenance, dams or reservoir utilization and waste water treatment for the benefit sharing of farming. The positive sides of all these policies are for the human civilization to thrive in a more economize and greener water ways.

References

Abrisqueta, J.M., Plana, V., Mounzer, O.H., Mendez, J. and Ruiz-Sanchez, M.C. 2007. Effects of soil tillage on runoff generation in a Mediterranean apricot orchard. *Agricultural Water Management* **93**(1): 11-18.

Adak, T., Kumar K. and Singh V.K. 2016. Energy summation indices and heat use efficiency in Mango cv Dashehari under subtropical Indian condition. *Journal of Agricultural Physics* **16** (1&2): 71-79.

Adak, T., Shukla, S.K., Kumar, K. and Singh, V.K. 2017. Perception of Soil and Water Conservation Issues and Mango Orchard Productivity - Farmer's Perspective. *In*: *Sustainable Farming and Soil Health Management,* Sanjay Arora and Suraj Bhan (Editors), Soil Conservation Society of India NASC Complex, Pusa, New Delhi, pp. 364-374.

Adak, T., Pandey, G. and Rajan, S. 2018. Soil Hydraulic properties in diverse fruit orchard ecosystem-an analysis. *Journal of Agricultural Physics* **18(2)**: 188-202.

Adamson, D., Loch, A. and Schwabe, K. 2017. Adaptation responses to increasing drought frequency. *Australian Journal of Agricultural and Resource Economics* **61**(3): 385-403.

Adekalu, K., Olorunfemi, I. and Osunbitan, J. 2007. Grass mulching effect on infiltration, surface runoff and soil loss of three agricultural soils in Nigeria. *Bioresource Technology* **98**: 912-917.

Alcántara, C., Pujadas, A. and Saavedra, M. 2011. Management of cruciferous cover crops by mowing for soil and water conservation in southern Spain. *Agricultural Water Management* **98**: 1071-1080.

Atucha, A., Merwin, I.A., Brown, M.G., Gardiazabal, F., Mena, F., Adriazola, C. and Lehmann, J. 2013. Soil erosion, runoff and nutrient losses in an avocado (*Persea americana* Mill) hillside orchard under different groundcover management systems. *Plant and Soil* **368(1-2)**: 393-406.

Bekele, W. and Drake, L. 2003. Soil and water conservation decision behavior of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. *Ecological Economics* **46**: 437-451.

Bennie, A.T.P. and Hensley, M. 2004. Advances in soil physics and soil water management research in South Africa, 1979-2003. *South African Journal of Plant and Soil* **21(5)**: 268-277.

Bigelow, D.P. and Zhang, H. 2018. Supplemental irrigation water rights and climate change adaptation. *Ecological Economics* **154**: 156-167.

Boland, A.M., Bewsell, D. and Kaine, G. 2006. Adoption of sustainable irrigation management practices by stone and pome fruit growers in the Goulburn/Murray Valleys, Australia. *Irrigation Science* **24(2)**: 137-145.

Brinegar, H.R. and Ward, F.A. 2009. Basin impacts of irrigation water conservation policy. *Ecological Economics* **69**: 414-426.

Cancela, J.J., Fandi˜no, M., Rey, B.J., Dafonte, J. and González, X.P. 2017. Discrimination of irrigation water management effects in pergola trellis system vineyards using a vegetation and soil index. *Agricultural Water Management* **183**: 70-77.

Cao, X., Yang, P., Engel, B. A. and Li, P. 2018. The effects of rainfall and irrigation on cherry root water uptake under drip irrigation. *Agricultural Water Management* **197**: 9-18.

Castro, G., Romero, P., Go´mez, J.A. and Fereres, E. 2006. Rainfall redistribution beneath an olive orchard. *Agricultural Water Management* **86**: 249-258.

Cui, L., Shi, J. and Ma, Y. 2019. Temporal and spatial variations of the thermal growing season in China during 1961-2015. *Meteorological Applications* **25(1)**: 56-65.

Czap, N.V., Czap, H.J., Banerjee, S. and Burbach M.E. 2019. Encouraging farmers' participation in the Conservation Stewardship Program: A field experiment. *Ecological Economics* **161**: 130-143.

Das, A., Gi, R., Choudhury, B.U., Munda, G.C., Patel, D.P., Ngachan, S.V., Ghosh, P.K., Tripathi, A.K., Das, S. and Kumar, M. 2012. Natural resource conservation through indigenous farming systems: Wisdom alive in North East India. *Indian Journal of Traditional Knowledge* **11(3)**: 505-513.

Duŕan Zuazo, V.H., Rodŕýguez Pleguezuelo, C.R., Arroyo Panadero, L., Marťýnez Raya, A., Francia Marťýnez, J.R. and Ćarceles Rodŕýguez, B. 2009. Soil conservation measures in rainfed olive orchards in south-eastern Spain: Impacts of plant strips on soil water dynamics. *Pedosphere* **19(4)**: 453-464.

Fernandez, M.A. 2017. Adoption of erosion management practices in New Zealand. *Land Use Policy* **63**: 236-245.

Ganjegunte, G. and Clark, J. 2017. Improved irrigation scheduling for freshwater conservation in the desert southwest U.S. *Irrigation Science* **35(4)**: 315-326.

Gao, L., Zhang, W., Mei, Y., Sam, A.G., Song, Y. and Jin, S. 2018. Do farmers adopt fewer conservation practices on rented land? Evidence from straw retention in China. *Land Use Policy* **79**: 609-621.

Giordano, R., D'Agostino, D., Apollonio, C., Scardigno, A., Pagano, A., Portoghese, I., Lamaddalena, N., Piccinni, A.F. and Vurro M. 2015. Evaluating acceptability of groundwater protection measures under different agricultural policies. *Agricultural Water Management* **147**: 54-66.

Hussain, S., Luro, F., Costantino, G., Ollitrault, P. and Morillon, R. 2012. Physiological analysis of salt stress behavior of citrus species and genera: low chloride accumulation as an indicator of salt tolerance. *South African Journal of Botany* **81**: 103-112.

Intrigliolo, D.S. and Castel, J.R. 2010. Response of plum trees to deficit irrigation under two crop levels: tree growth, yield and fruit quality. *Irrigation Science* **28(6)**: 525-534.

Jain, S.K. 2019. Water resources management in India - challenges and the way forward. *Current Science* **117(4)**: 569-576.

Jin, S., Wang, Y., Shi, L., Guo, X. and Zhang, J. 2018a. Effects of pruning and mulching measures on annual soil moisture, yield, and water use efficiency in jujube (*Ziziphus jujube* Mill.) plantations. *Global Ecology and Conservation* **15**: e00406.

Jin, Y., He, R., Marino, G., Whiting, M., Kent, E., Sanden, B.L., Culumber, M., Ferguson, L., Little, C., Grattan, S., Paw U, K.T., Lagos, L.O., Snyder, R.L. and Zaccaria, D. 2018b. Spatially variable evapotranspiration over salt affected pistachio orchards analyzed with satellite remote sensing estimates. *Agricultural and Forest Meteorology* **262**: 178-191.

Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z. and Cerdà, A. 2018. The superior effect of nature based solutions in land management for enhancing ecosystem services. *Science of the Total Environment* **610-611**: 997-1009.

Keesstra, S., Pereira, P., Novara, A., Brevik, E.C., Azorin-Molina, C., Parras-Alcántara, L., Jordán, A. and Cerdà, A. 2016. Effects of soil management techniques on soil water erosion in apricot orchards. *Science of the Total Environment* **551-552**: 357-366.

Kessler, C.A. 2007. Motivating farmers for soil and water conservation: A promising strategy from the Bolivian mountain valleys. *Land Use Policy* **24**: 118-128.

Levin, A.G., Peres, M., Noy, M., Love, C., Gal, Y. and Naor, A. 2018. The response of field-grown mango (cv. Keitt) trees to regulated deficit irrigation at three phenological stages. *Irrigation Science* **36(1)**: 25-35.

Liu, Y., Tao, Y., Wan, K.Y., Zhang, G.S., Liu, D.B., Xiong, G.Y. and Chen, F. 2012. Runoff and nutrient losses in citrus orchards on sloping land subjected to different surface mulching practices in the Danjiangkou Reservoir area of China. *Agricultural Water Management* **110**: 34-40.

Lussier, J.M., Krzic, M., Smukler, S.M., Bomke, A.A. and Bondar, D. 2018. Short-term effects of grassland set-asides on soil properties in the Fraser River delta of British Columbia. *Canadian Journal of Soil Science* DOI: https://doi.org/10.1139/cjss-2018-0097.

Madhusoodhanan, C.G., Sreeja, K.G. and Eldho, T.I. 2016. Climate change impact assessments on the water resources of India under extensive human interventions. *Ambio* **45**: 725-741.

Marshall, E., Ailery, M., Malcolm, S. and Williams, R. 2015. Agricultural production under climate change: the potential impacts of shifting regional water balances in the United States. *American Journal of Agricultural Economics* **97(2)**: 568-588.

Mishra, A.K. 2019. Quantifying the impact of global warming on precipitation patterns in India. *Meteorological Applications* **26(1)**: 153-160.

Moreno-Ramón, H., Quizembe, S., Ibáñez-Asensio, S. 2014. Coffee husk mulch on soil erosion and runoff: experiences under rainfall simulation experiment. *Solid Earth* **5**: 851-862.

Mouron, P., Scholz, R.W., Nemecek, T. and Weber, O. 2006. Life cycle management on Swiss fruit farms: Relating environmental and income indicators for apple-growing. *Ecological Economics* **58**: 561-578.

Nuberg, I.K. and Evans, D.G. 1993. Alley cropping and analog forests for soil conservation in the dry uplands of Sri Lanka. *Agroforestry Systems* **24(3)**: 247-269.

Panigrahi, P., Srivastava, A.K. and Huchche, A.D. 2009. Influence of *in-situ* soil and water conservation measures on performance of Nagpur mandarin. *Journal of Agricultural Engineering (ISAE)* **46**(3): 37-40.

Panigrahi, P., Srivastava, A.K., Panda, D.K. and Huchche, A.D. 2017. Rainwater, soil and nutrients conservation for improving productivity of citrus orchards in a drought prone region. *Agricultural Water Management* **185**: 65-77.

Perea, R.G., García, I.F., Arroyo, M.M., Rodríguez Díaz, J.A., Poyato, E.C. and Montesinos, P. 2017. Multiplatform application for precision irrigation scheduling in strawberries. *Agricultural Water Management* **183**: 194-201.

Podwojewski, P., Janeau, J.L., Grellier, S., Valentin, C., Lorentz, S. and Chaplot, V. 2011. Influence of grass soil cover on water runoff and soil detachment under rainfall simulation in a sub humid South African degraded rangeland. *Earth Surface Processes and Landforms* **36**: 911-922.

Qian, B., Gameda, S., Zhang, X. and Jong, R.D. 2011. Changing growing season observed in Canada. *Climatic Change* DOI 10.1007/s10584-011-0220-8.

Qureshi, M.E., Whitten, S.M. and Franklin, B. 2013. Impacts of climate variability on the irrigation sector in the southern Murray-Darling Basin, Australia. *Water Resource and Economics* **4**: 52-68.

Rawat, S.S., Prashar, P., Rawat, K.S., Nikam, B.R. and Kumar, P. 2017. Prioritization of sub-watersheds of a western Himalayan catchment employing morphologically based compound index and sediment production rate. *Journal of Agricultural Physics* **17(1)**: 73-86.

Rodrigo-Comino, J., Taguas, E., Seeger, M. and Ries, J.B. 2018. Quantification of soil and water losses in an extensive olive orchard catchment in Southern Spain. *Journal of Hydrology* **556**: 749-758.

Romero-Trigueros, C., Nortes, P.A., Alarcón, J.J., Hunink, J.E., Parra, M., Contreras, S., Droogers, P. and Nicolás, E. 2017. Effects of saline reclaimed waters and deficit irrigation on Citrus physiology assessed by UAV remote sensing. *Agricultural Water Management* **183**: 60-69.

Romero-Trigueros, C., Nortes, P.A., Pedrero, F., Mounzer, O., Alarcón, J.J., Bayona, J.M. and Nicolás, E. 2014. Assessment of the sustainability of using saline reclaimed water in grapefruit in medium to long term. *Spanish Journal of Agricultural Research* **12(4)**: 1137-1148.

Roointan, R., Yadollahi, A., Khorami, S.S., Arab, M.M. and Vahdati, K. 2018. Rainfed fruit orchards in sloping lands: soil erosion reduction, water harvesting and fruit production. DOI: 10.17660/ActaHortic.2018.1190.18.

Saxena, A., Kumar, P., Goyal, R.K., Patel, N. and Khapte, P.S. 2016. Assessment of Water Productivity of Different Cropping Systems under Drip Irrigation in Arid Region of Western India. *Annals of Arid Zone* **55**(3&4): 101-105.

Stoate, C., Jones, S., Crotty, F., Morris, C. and Seymour, S. 2019. Participatory research approaches to integrating scientific and farmer knowledge of soil to meet multiple objectives in the English East Midlands. *Soil Use and Management* **35**: 150-159.

Sweet, S.K., Wolfe, D.W., DeGaetano, A. and Benner, R. 2017. Anatomy of the 2016 drought in the Northeastern United States: Implications for agriculture and water resources in humid climates. *Agricultural and Forest Meteorology* **247**: 571-581.

Tadayonnejad, M., Mosaddeghi, M.R. and Dashtaki, S.G. 2017. Changing soil hydraulic properties and water repellency in a pomegranate orchard irrigated with saline water by applying poly-acrylamide. *Agricultural Water Management* **188**(C): 12-20.

Tomaszkiewicz, M., Najm, M.A., Zurayk, R. and El-Fadel, M. 2017. Dew as an adaptation measure to meet water demand in agricultureand reforestationM. *Agricultural and Forest Meteorology* **232**: 411-421.

Tu, A., Xie, S., Yu, Z., Li, Y. and Nie, X. 2018. Long-term effect of soil and water conservation measures on runoff, sediment and their relationship in an orchard on sloping red soil of southern China. *PLoS ONE* **13(9)**: e0203669.

Valverde, P., Serralheiro, R., Carvalho, M., Maia, R., Oliveira, B. and Ramos, V. 2015. Climate change impacts on irrigated agriculture in the Guadiana river basin (Portugal). *Agricultural Water Management* **152**: 17-30.

Wang, J., Huang, J., Wu, P., Zhao, X., Gao, X., Dumlao, M. and Si, B.C. 2015. Effects of soil managements on surface runoff and soil water content in jujube orchard under simulated rainfalls. *Catena* **135**: 193-201.

Xia, X.H., Wu, Q., Mou, X.L. and Lai, Y.J. 2015. Potential impacts of climate change on the water quality of different water bodies. *Journal of Environmental Informatics* **25**(2): 85-98.

Xu, Q.,Wang, T., Cai, C., Li, Z. and Shi, Z. 2012. Effects of soil conservation on soil properties of citrus orchards in the Three Gorges Area, China. *Land Degradation and Development* **23**: 34-42.

Zema, D.A., Nicotra, A. and Zimbone, S.M. 2019. Improving management scenarios of water delivery service in collective irrigation systems: a case study in Southern Italy. *Irrigation Science* **37(1)**: 79-94.

Zuo, A., Nauges, C. and Wheeler, S.A. 2015. Farmers' exposure to risk and their temporary water trading. *European Review of Agricultural Economics* **42(1)**: 1-24.

Received: January 7, 2019; Accepted: March 19, 2019