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Assessment of soil properties in *Melia dubia* based agroforestry system in semi-arid part of Haryana

Krishma Nanda, Sandeep Arya, Bojja Harish Babu, JS Ranawat, Ashish Kumar and Tarun Kumar

Abstract
The objective of the present study was to assess various properties of soil in 4 year old *Melia dubia* plantation at 3m × 3m distance in Haryana, intercropped with five barley varieties. Samples were collected at 0 to 15 cm, 15 to 30 cm and 30-45 cm soil depth in both intercropped and control conditions (field without trees) and at a distance of 0.5m, 1m, and 1.5m from the tree line. Soil samples were analyzed for pH, electrical conductivity (EC), organic carbon, soil moisture and available nitrogen, phosphorus & potassium. The electrical conductivity of soil decreased from 0.43-0.39 dSm^{-1} (under trees) and 0.35-0.33 dSm^{-1} (control) at 0-15 cm of soil depth. Results revealed a slight decrease (8.10 to 7.90 and 8.30 to 8.29) in soil pH under trees at both soil depths *i.e.* 0-15cm and 15-30 cm respectively. The soil pH and EC decreased more under trees than under control. However, amount of N,P,K and organic carbon was found higher in intercropped conditions at both soil depths (0-15 cm & 15-30 cm). Soil moisture content in the soil was found higher under plantation. The present study indicates that growing trees has positive correlation with soil health.

Keywords: *Melia dubia* tree, pH, Electrical conductivity (EC), Organic carbon, Soil moisture, Soil nutrients

Introduction

Trees in agroforestry systems offer a great relief to farm soil by providing ample amount of nutrients, intangible benefits and by ameliorating the environment for raising of crops. With the increase in agricultural innovations human intensification of agriculture in Haryana has increased food production to a greater extent but along with this it has caused extreme deterioration to environment. Soil erosion has impacted almost half of the croplands all over the world, caused decline in fertility of soil, reduction in biodiversity and various socio-ecological concerns (Udawatta and Jose 2012; Waldron *et al.*, 2017) [44, 45]. Agroforestry has always been endorsed for its carbon sequestration potential and other allied benefits such as improved nutrient content in soil, soil erosion, runoff control and providing different socio-economic benefits and ultimately greater agricultural productivity (Brown *et al.* 2018; Muchane *et al.* 2020; Shin *et al.*, 2020) [10, 24, 33]. The Physico-chemical properties of soil improve through decomposition of leaf litter added by perennial tree species. Tree species like *Melia dubia* have a significant impact on soil properties, which could help to nurture farm lands through addition of large amount of leaf litter. Establishment of permanent tree cover of suitable tree species on farm lands could provide solution through lowering soil pH and increasing the organic matter content in soil. Studies have shown that tree plantation improved many soil Physico-chemical properties (Belsky *et al.*, 1989) [7]. Reduction of soil pH, electrical conductivity, improvement of water permeability, water holding capacity, improvement of infiltration rate, soil fertility and other features are characteristics of soil as influenced by tree species. Agroforestry improves soil productivity apart from providing an assurance to the farmers against any uncertainty (Arya and Toky 2017). Microbial biomass and their activity enhancement and microclimatic improvement under tree canopies compared to open areas especially in arid and semiarid areas have been reported earlier (Tewari *et al.*, 2013) [41]. Carbon constitutes almost 50% of the dry weight of branches and 30% of foliage while below ground carbon sequestration accounts for a larger part up to 2/3 of total including roots, below ground plant parts, living organisms present in soil and carbon present at various soil horizons (Nair *et al.*, 2010) [26]. Besides economical utilities, environmental services are also offered by the trees. *Melia dubia* commonly known as Burma Dek and Malabar Neem is a fast rotation tree species, it adds higher amount of litter into soil and promises better growth of crop growing under it. *Melia* Trees in agroforestry systems offer a great relief to farm soil by providing ample amount of nutrients, intangible benefits and by ameliorating the environment for raising of crops. With the increase in agricultural innovations human intensification of agriculture in Haryana has increased food production to a greater extent but along with this it has caused extreme deterioration to environment. Soil erosion has impacted almost half of the croplands all over the world, caused decline in fertility of soil, reduction in biodiversity and various socio-ecological concerns (Udawatta and Jose 2012; Waldron *et al.*, 2017) [44, 45]. Agroforestry has always been endorsed for its carbon sequestration potential and other allied benefits such as improved nutrient content in soil, soil erosion, runoff control and providing different socio-economic benefits and ultimately greater agricultural productivity (Brown *et al.* 2018; Muchane *et al.* 2020; Shin *et al*., 2020) [10, 24, 33]. The Physico-chemical properties of soil improve through decomposition of leaf litter added by perennial tree species. Tree species like *Melia dubia* have a significant impact on soil properties, which could help to nurture farm lands through addition of large amount of leaf litter. Establishment of permanent tree cover of suitable tree species on farm lands could provide solution through lowering soil pH and increasing the organic matter content in soil. Studies have shown that tree plantation improved many soil Physico-chemical properties (Belsky *et al*., 1989) [7]. Reduction of soil pH, electrical conductivity, improvement of water permeability, water holding capacity, improvement of infiltration rate, soil fertility and other features are characteristics of soil as influenced by tree species. Agroforestry improves soil productivity apart from providing an assurance to the farmers against any uncertainty (Arya and Toky 2017) [3]. Microbial biomass and their activity enhancement and microclimatic improvement under tree canopies compared to open areas especially in arid and semiarid areas have been reported earlier (Tewari *et al.*, 2013) [41]. Carbon constitutes almost 50% of the dry weight of branches and 30% of foliage while below ground carbon sequestration accounts for a larger part up to 2/3 of total including roots, below ground plant parts, living organisms present in soil and carbon present at various soil horizons (Nair *et al*., 2010) [26]. Besides economical utilities, environmental services are also offered by the trees. *Melia dubia* commonly known as Burma Dek and Malabar Neem is a fast rotation tree species, it adds higher amount of litter into soil and promises better growth of crop growing under it. *Melia dubia* tree creates very suitable environmental conditions for crop beneath its canopy. *Melia dubia* being a multipurpose tree provide various benefits to the farmers. It fetches a handsome price in the market with assured buy back. Along with providing food for human, it improves socio-economic status of the farmers through increasing sources of income. Matured Leaves of *Melia dubia* are rich source of mineral elements, crude protein, crude lipid and vitamins and make excellent fodder for ruminants (Saravanan *et al.*, 2013) [32]. Inclusion of tree species on agricultural systems can also optimize the nutrient recycling and have positive effects on soil physical and chemical properties. The specie has been reported to have transient or null allelopathic effect on understorey crops hence could be a promising agroforestry ideotype. Trees contribute to environment in a number of ways in both rural and urban areas; they perform an important role in the ecosystem. Trees can provide various benefits in rural areas *i.e.* economic stability, food security, household income and thermal comfort (shade). Trees present in agricultural domain improve nutrient cycling and ensure beneficial effects on physical and chemical properties of soil. Trees ameliorate the soil to various degrees through the addition of large amount of organic matter and nutrients from litter and fine roots. Agroforestry systems get abundant nutrient stock litter decomposition and mineralization supplies which subsequently increases crop yields. This paper mainly studies the effect of *Melia dubia* based agroforestry system and explores the relation among trees and soil.

Material and method

The present study estimates the changes in soil fertility and moisture content in a four year old plantation of *Melia dubia* having barley crops grown in the interspaces of trees. The study was carried out at a farmer field at village Gillan Khera in district Fatehabad, situated in the semi-arid region of Haryana during 2018-2019.The experimental site was located at 29˚50’ latitude and 75˚30’ longitude at an altitude of 212 m above the mean sea level in the semi-arid belt of north-western India. Regional climate of the location is subtropical-monsoonic. This place receives an average annual rainfall of 360-400 mm, out of which 70-80 per cent occurs during July to September. The mean maximum temperature in May and June during summer months ranges from 40 to 45 °C and minimum temperature may reach as low as 0 °C in December and January. Hence, place witness very hot summers and cold winters. The present study was conducted in an already established four-year old plantation of *Melia dubia* planted at a spacing of 3m × 3m at village Gillan Khera in district Fatehabad situated in western part of Haryana. In the interspaces of the four year old *Melia dubia* trees, five barley varieties were raised in four replication plots during Rabi season (winter) of 2018-19. The standard package of practices as recommended by CCS Haryana Agricultural University was followed. Soil samples were collected randomly at different depths (0-15 cm, 15-30 cm, 15-45 cm) from the experimental field in three replicates. This was done twice i.e. prior to sowing (November) and later after harvesting (April) of barley crop. Soil samples were analyzed for electrical conductivity, pH and organic carbon and nutrients (nitrogen, phosphorus and potassium).First air-drying of soil samples was done and then ground in a wooden pestle and mortar, the grounded soil was passed from a stainless steel sieve of 2 mm. The soil obtained was stored for analysis. The pH and EC of the soil were determined with distilled water suspension (1:2). Soil nutrients were estimated following standard procedures. Soil samples for soil moisture readings were taken at 0.5m, 1m, and 1.5m distance away from the tree line. Samples were taken three times *i.e.* before irrigation and 7th and 14th day after irrigation. The data recorded during the research was analyzed statistically by the method given by Panse and Sukhatme in 1985.

Result & Discussion

Decrease in values of soil pH (Table 1) was observed under trees after harvest as compared to its initial value while, there was negligible change in control (field without trees) from November 2018 to April 2019. This may be due to microclimate created by crop and tree root system and the acidic nature of litter fall which decreased the soil pH after decomposition (Behera *et al.*, 2016; Brandani *et al.*, 2017) [6, 9]. The results revealed maximum decrease (8.10 to 7.90 and

8.30 to 8.29) in soil pH under trees at both soil depths *i.e*. at 0-15 and 15-30 cm respectively. The lowest (7.90) pH value was noted beneath trees after harvest at 0-15 cm soil depth. The decrease in soil pH was more under *Melia* plantation than in control (without tree). The marginally lower pH under agri-silvicultural system than in control (without tree) might be owing to considerable accumulation of organic matter beneath trees and discharge of organic acids (weak) at the time of decomposition of litter (Prasadini and Sreemannarayana 2007; Kumar *et al.*, 2008) [31, 22].

Table 1: Soil pH and organic carbon content at different depth before sowing and after harvesting of barley varieties in control (field without trees) and under tree condition

	Soil pH						**Organic carbon (%)**					
Soil Depth (cm)	**Before sowing**			**After harvest**			**Before sowing**			**After harvest**		
	Under Tree	**Without Tree**	**Mean**	**Under Tree**	**Without Tree**	**Mean**	**Under Tree**	**Without Tree**	**Mean**	**Under Tree**	**Without Tree**	**Mean**
0-15	8.10	7.92	8.01	7.90	7.90	7.90	0.42	0.34	0.38	0.44	0.33	0.39
15-30	8.30	7.90	8.10	8.29	7.90	8.09	0.27	0.22	0.25	0.28	0.21	0.24
Mean	8.20	7.91		8.09	7.90		0.35	0.28		0.36	0.27	
C. D. at 5%												
Depth	NS			0.17			0.01			0.01		
Environment	0.25			0.17			0.01			0.01		
D×E	NS			0.25			0.01			0.01		

*D×E—Depth × Environment

The soil organic carbon (Table 1) under *Melia dubia* plantation increased significantly at both (0-15 and 15-30 cm) soil profile depths over the initial status of organic carbon. The organic carbon content of the soil increased in tree integrated plots and found significantly higher (0.44%) at 0-15cm compared to 15-30 cm *i.e.* (0.28%) recorded after harvesting of barley varieties. The soil organic carbon decreased in open conditions from 0.34 to 0.33% and 0.22 to 0.21% after harvest at both soil depth *i.e.*0-15 and 15-30 cm respectively. The maximum increase (0.02%) in soil organic carbon was observed at 0-15 cm soil depth in intercropped condition. The reason for lesser soil organic carbon in the field without trees might be due to lack of lignified cells in agricultural residues. The other reason might be owing to complete exposure of soil to the sun. Reason for higher organic matter content in intercropped conditions could be credited to the leaf fall occurring in *Melia dubia* during winter months. This leaf fall mass gets decomposed after its incorporation into the soil which ultimately adds to the carbon pool of soil. Enrichment of soil in carbon content in tree based systems is owing to various aspects *i.e.* timely litter addition into the soil, recycling of annual root fine biomass and root exudates and its reduced oxidation of organic substance under the tree shade (Gill and Burman 2002) [17]. Tree based cropping system add large amount of litter hence, ultimately increase amount of organic matter content in the soil[2]. However, proper increase in organic matter of soil could be experienced only after at least 5-10 years of adoption of such crop raising systems (Derpsch *et al.*, 2008) [13]. Climate conditions are also responsible for the addition of carbon content in the soil, as humidity and temperature influence microbial activity up to a great extent and ultimately breakdown of organic substance (Nair *et al.,* 2010) [26]. Low carbon content level was reported in the study of African Sahel as compared to the high temperature zone in the same region (Takimoto *et al.*, 2008) [40]. The soil organic carbon is a function of the rate of decomposition and replacement of the organic matter content into the soil. Integration of the trees and crops on farmlands improves soil organic matter content through litter addition in both above and below ground. Organic matter content in the soil is acknowledged as the chief reflector of soil health since it act as a source of energy for the organisms present in soil and influences their diversity and various biological functions (Dollinger and Jose 2018) [15]. Study in the traditional Savannah of Cameroon for global carbon storage of plots afforested with *Eucalyptus* specie revealed on comparison that carbon storage in *Eucalyptus* stands was larger than traditional Savannahs (Noumi *et al.*, 2018) [27]. Area under canopy have larger stock of carbon and nitrogen *i.e.* area having litter fall as compared to open prairie (Hoosbeek *et al.*, 2018) [19]. Soil organic carbon content levels in both aggregate types (water stable and dry-stable) were found greater in poplar-based and guava-based agri-silviculture systems study as compared to sole (without tree) (Dhaliwal *et al.*, 2018) [14]. The amount of organic matter in the soil is the most significant ecological element that influences the viability of a terrestrial ecosystem since it influences the physical, chemical, and biological properties of the soil, making it a core attribute of soil fertility. Because of the constant inclusion of litter and decomposition operations, the ecological processes in agroforestry systems make the environment more effective in terms of carbon stocking and nutrient cycling. This emphasizes the importance of trees in farmland ecosystems. It may be suggested that agroforestry implementation could assist in long-term mitigation of climate change impacts by not only sequestering more carbon in its biomass but also accumulating soil organic carbon by litter recycling (Singh *et al.*, 2019) [36]. Degraded soils often have low levels of SOM. Thus, increasing SOM is essential to recovery of the quality of these soils, which can be achieved by introducing plants into the system. SOM is important for the proper functioning and protection of the edaphic system (Siqueira *et al.*, 2019) [37].

Table 2: Soil EC and nitrogen content at different depth before sowing and after harvesting of barley varieties in control (field without trees) and under tree condition

Soil Depth (cm)	Soil EC						Available nitrogen (kg/ha)					
	Before sowing			After harvest			Before sowing			After harvest		
	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean
0-15	0.43	0.50	0.46	0.39	0.49	0.44	129.21	109.62	119.41	130.42	108.42	119.42
15-30	0.35	0.41	0.38	0.33	0.39	0.36	125.23	107.41	116.32	125.90	107.01	116.46
Mean	0.39	0.45		0.36	0.44		127.22	108.52		128.16	107.72	
C. D. at 5%												
Depth	0.01			0.001			2.83			NS		
Environment	0.01			0.006			2.83			3.99		
D×E	NS			0.009			NS			NS		

*D×E—Depth × Environment

The electrical conductivity at both soil depths decreased under *Melia dubia* based agroforestry system. (Table 2)The rate of decrease in electrical conductivity was comparatively lower in control (field without trees). The maximum reduction in EC was recorded in intercropped condition at a soil depth of 0-15 cm. Similar observations regarding pattern of electrical conductivity were reported by various researchers (Patel *et al.,* 2010) [28].

Trees alter soil properties through a variety of mechanisms. Root networks of trees and crops play a critical part in these interactions, since they are involved in the majority of belowground processes which influence soil functions. A greater knowledge of processes at the intersection of soil science and agroforestry, such as soil organic carbon sequestration or water infiltration, may thus aid in the achievement of some of the UN Sustainable Development Goals (Cardinal *et al*., 2020). There was improvement in the available nitrogen (Table 2) content in the soil at harvest might be due to the increase in the humus content of soil after decomposition of litter fall of *Melia dubia* trees. Similar findings were reported in an *Acacia*-based agri-silviculture system (Githae *et al.,* 2011) [18]. They reported that the nitrogen content of soil under agri-silvicultural system increased because of litter fall accumulation by *Acacia*. Similar results of improvement in the nutrient status of soil due to intercropping in an agroforestry have been reported earlier (Bhardwaj *et al.* 2017; Sirohi and Bangarwa 2017) [8, 38]. The increase in nitrogen content under agroforestry may be due to reason that a high moisture level associated with more moderate temperature in shade may result in a faster rate of mineralization, breakdown of litter, and turnover of N than occurs in full sunlight. Non N- fixing trees can also enhance soil physical, chemical and biological properties by adding significant amount of organic matter and releasing and recycling of nutrients in agroforestry systems (Antonio and Gama-Rodrigues 2011) [18]. Sto¨cker *et al.* (2020) [39] found that agri-silviculture system encouraged positive alterations in soil physical traits and resulted in consistent enhancement of soil quality. Researchers suggested diversified root systems of tree and accumulation of crop residues for the speedy enhancement of quality of soil. Agroforestry provides an approach through which in a very little time organic content could be added by selection of proper nitrogen fixing tree species and if they are fast growing too (Tsufac *et al.,* 2021) [43].

Table 3: Soil phosphorus and potassium content at different depth before sowing and after harvesting of barley varieties in control (field without trees) and under tree

Soil Depth (cm)	Available phosphorus (kg/ha)						Available potassium (kg/ha)					
	Before sowing			After harvest			Before sowing			After harvest		
	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean	Under Tree	Without Tree	Mean
0-15	15.20	13.50	14.35	16.10	13.30	14.70	298.30	249.50	273.90	302.40	252.90	277.65
15-30	8.33	7.40	7.86	8.50	7.30	7.90	290.20	245.30	267.75	297.33	249.50	273.41
Mean	11.76	10.45		12.30	10.30		294.25	247.40		299.86	251.20	
C. D. at 5%												
Depth	0.13			0.26			NS			NS		
Environment	0.13			0.26			7.54			5.88		
D×E	0.19			0.37			NS			NS		

*D×E—Depth × Environment

Available phosphorus (Table 3) in soil exhibited similar trend as of soil nitrogen. Phosphorus content in soil increased after harvest when compared to initial values. The increase in phosphorus content of soil was recorded greater at soil depth of 0-15 cm under tree conditions compared to 15-30 cm of soil depth. Potassium (Table 3) content of soil was higher under *Melia dubia* trees intercropped with barley varieties as compared to the control (barley varieties grown without trees). An increase in potassium content was observed after harvest when compared to initial values in both the environments. According to a study higher level of pH and base saturation was noted in parts grown in intercropping with *Hevea brasiliensis* compared to monocultures. Compared to the open savanna higher level of microbial biomass and N, P, K, content was observed beneath the tree crowns. Researchers also pointed the importance of birds and mammals present in the vicinity of trees and their role in nutrient deposition through dung (Belsky *et al.*1989) [7]. The higher available nutrient content in *Melia dubia* based agroforestry system over the agricultural system may be attributed to litter-fall addition from *Melia dubia* trees as well as addition of root residues.

Table 4: Soil moisture status at different soil depth and distance form tree row for first and second irrigation in sole and under tree condition

First irrigation																		
Soil Depth (cm)	**Before irrigation**						**After 7 days of irrigation**						**After 14 days of irrigation**					
	0.5 m		**1 m**		**1.5 m**		**0.5 m**		**1 m**		**1.5 m**		**0.5 m**		**1 m**		**1.5 m**	
	UT	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**
0-15	12.01	9.40	12.00	9.20	11.90	8.90	16.30	11.10	16.23	10.77	15.90	10.40	14.70	9.80	14.50	9.70	14.20	9.43
15-30	12.32	9.70	12.30	9.60	11.80	9.17	18.80	16.50	18.63	16.27	18.20	15.90	13.20	12.20	13.00	12.23	12.80	11.87
30-45	12.91	10.12	12.70	10.10	12.30	9.80	19.00	16.61	18.83	16.50	18.40	16.20	15.40	14.60	15.17	14.53	15.10	14.20
CD at 5%	Distance= 0.20; Depth= 0.20; Distance × Depth = NS; Environment= 1.6; Distance × Environment=NS; Depth × Environment = NS; Distance × Depth× Environment=NS						Distance= 0.30; Depth= 0.30; Distance × Depth = NS; Environment= 0.2; Distance × Environment =NS; Depth × Environment = 0.42; Distance × Depth× Environment= NS						Distance= 0.26; Depth=0.26; Distance × Depth =NS; Environment=0.21; Distance × Environment =NS; Depth × Environment =0.36; Distance × Depth× Environment=NS					
Second irrigation																		
Soil Depth (cm)	**Before irrigation**						**After 7 days of irrigation**						**After 14 days of irrigation**					
	0.5 m		**1 m**		**1.5 m**		**0.5 m**		**1 m**		**1.5 m**		**0.5 m**		**1 m**		**1.5 m**	
	UT	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**	**UT**	**WT**
0-15	11.90	9.20	11.70	9.10	11.50	8.93	18.30	17.62	18.20	17.50	17.90	17.13	10.83	9.50	10.63	9.33	10.50	9.10
15-30	11.90	11.01	11.73	10.87	11.20	10.47	19.40	18.30	19.17	18.10	19.00	17.77	11.40	10.20	11.00	9.83	10.90	9.70
30-45	12.30	11.81	12.07	11.70	11.80	11.10	20.40	17.40	20.07	17.20	19.80	17.00	11.83	10.40	11.40	10.13	11.20	9.90
CD at 5%	Distance= 0.17; Depth= 0.17; Distance × Depth = NS; Environment= 0.14; Distance × Environment = NS; Depth × Environment =0.24; Distance × Depth× Environment= NS						Distance=0.34; Depth= 0.34; Distance × Depth = NS; Environment= 0.28; Distance × Environment = NS; Depth × Environment =0.49; Distance × Depth× Environment= NS						Distance=0.19; Depth=0.19; Distance × Depth = NS; Environment=0.15; Distance × Environment =NS; Depth × Environment =NS; Distance × Depth× Environment=NS					

of barley varieties and trees. Tree based cropping system increase soil fertility and nutrient status of the soil (Toky *et al.* 2018; Sida *et al.*, 2020) [42].

Owing to their higher spatial complexity and biodiversity, agroforestry systems are supposed to facilitate water cycling processes (*e.g.*, water infiltration and retention, decreased run-off) and hydrological ecosystem resources better than intensive monoculture (Pavlidis and Tsihrintzis 2018) [29]. Agroforestry systems have the ability to increase water retention by complementary root distributions, with trees having deeper root systems than annual crops (Germon *et al*., 2016) [16]. An increasing trend of soil moisture (Table 4) content was observed while going deeper into soil profile in both the conditions of crop environment. While a decreasing pattern was recorded while moving away from tree row (0.5 m, 1 m, 1.5 m). The phonological behaviour of *Melia dubia* being deciduous in nature helps in conservation of moisture in soil probably due to presence of litter as mulch restricting loss of moisture through evaporation and also in Rabi season *Melia dubia* growth is restricted because it enters dormancy and intakes lesser amount of water for transpiration. Agri-silvicutural system improves water use efficiency, help in reducing components that are less productive *i.e.* evaporation, drainage and runoff (Bayala and Wallace 2015 [5]; Ling *et al.* 2020; Huo *et al.* 2020) [23]. Positive effects on agricultural crops arise through improved water relations (Muthuri *et al.*, 2014) [25]. As noted by the researchers, efficiency of bioinnocculants composed of rhizobacteria, phosphate solubilizing bacteria and AMF were more under the shade (Shukla *et al.* 2018) [34]. Agri-silvicultuarl systems are capable to enrich soil organic carbon superiorly as compared to mono-cropping; it is capable of enhancing nutrient availability and fertility in the soil owing to the existence of tree component (Dollinger and Jose 2018) [15]. Agroforestry is a potential system which promises improvement in soil condition, which is helpful and required for the upcoming generations. To restore the health and well-being of soil it is essential that communities involved in agriculture and policymakers should pay their attention to agri-silviultural systems. Root competition between crops and trees is a natural occurrence and farmers may mitigate it to some degree by employing strategies such as crown reduction, tree pruning, and proper tree and crop selection. Bayala and Prieto (2020) [4].

Agroforestry provides an opportunity to raise crops in purely organic form which in turn maintains soil health. Tree and crop species can be grouped into infinite number arrangements and species combinations. Majorly it depends upon the objective of the farmer and environmental features of the area (Pinho *et al.* 2012) [30]. No negative effects have been found on growth and yield of crops growing beneath in *Melia dubia* based agro-forestry system (Kulkarni 2017) [21]. Agroforestry systems so far are being identified by farmers as an additional income source; however knowledge of intangible benefits agroforestry system provides such as soil improvement is confined to scientific community only. The lack of quantitative information about the production of various crops when they compete for resources with trees is a significant impediment to the implementation of this scheme. (Artru *et al.*, 2017) [2]. Agroforestry systems have a great potential for above ground carbon sequestration in addition it add to the carbon stock of soil in large amount. Farmers should incorporate trees in their farm lands in order to reclaim the soil and to increase soil fertility.

Conclusion

A considerable change in soil chemical properties was observed under *Melia dubia* based agri-silvicultural system over control (field without trees). The soil pH and EC decreased more under *Melia dubia* trees than under control (field without trees). The soil organic carbon and available soil N, P and K increased significantly under *Melia dubia* plantation compared to control (field without trees) in both 0-15 cm and 15-30 cm soil depths. Soil moisture content in the soil was found higher under *Melia dubia* plantation when compared to control (without tree) at all the soil depths i.e. (0-15 cm, 15-30 cm, 30-45 cm). Soil moisture content decreased while going away from tree line. Results from the study revealed the beneficial effects of *Melia dubia* on farm soil and suggests it as a potential tree to cope up degrading agricultural lands in semi-arid regions.

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References
1. Antonio C, Gama- R. Soil organic matter, nutrient cycling and biological dinitrogen fixation in agroforestry systems. Agroforestry Systems 2011;81:191-193.
2. Artru S, Garré S, Dupraz C, Hiel MP, Blitz FC, Lassois L. Impact of spatio-temporal shade dynamics on wheat growth and yield, perspectives for temperate agroforestry. Eur J Agron. 2017;82:60-70.
3. Arya S, Toky OP. Biomass production in poplar agroforestry systems in Haryana of North Western India. Indian Journal of Ecology 2017;44(6):785-787.
4. Bayala J, Prieto I. Water acquisition, sharing and redistribution by roots: applications to agroforestry systems. Plant Soil 2020. https://doi.org/10.1007/s11104-019-04173-z
5. Bayala J, Wallace JW. The water balance of mixed tree-crop systems In. In: Black C, Wilson J, Ong CK, (Eds.), Trees-Crop Interactions: Agroforestry in a Changing Climate. CABI 2015, 140-190.
6. Behera LK, Patel DP, Gunaga RP, Mehta AA, Jadeja DB. Clonal evaluation for early growth performance of *Eucalyptus* in South Gujarat, India. Journal of Applied and Natural Science 2016;8(4):2066-2069.
7. Belsky AJ, Amundson RG, Duxbiry JM, Riha SJ, Ali AR, Mwonga SM. The effect of trees on their physical, chemical and biological environment in a semi- arid savanna in Kenya, Journal of Applied Ecology 1989;26(3):1005-1024.
8. Bhardwaj KK, Dhillon RS, Kumari S, Johar V, Dalal V, Chavan SB. Effect of *Eucalyptus* Bund Plantation on Yield of Agricultural Crops and Soil Properties in Semi-Arid Region of India, International Journal of Current Microbiology and Applied Science 2017;6(10):2059-2065.
9. Brandani CB, Rocha JHT, Godinho T de O, Wenzel AVA, Gonçalvese JLM. Soil C and Al availability in tropical single and mixed-species of *Eucalyptus* sp. and *Acacia mangium* plantations. Geoderma Regional. 2017;10:85-92.
10. Brown SE, Miller DC, Ordonez PJ, Baylis K. Evidence for the impacts of agroforestry on agricultural productivity, ecosystem services, and human well-being in high-income countries: a systematic map protocol. Environ Evid 2018;7:24 https://doi.org/10.1186/s13750-018-0136-0
11. Burgess PJ, Stephen W, Anderson, Durston GJ. Water use by a poplar wheat agroforestry system. Vegetation management in forestry, amenity and conservation areas: managing for multiple objectives, University of York, UK. Aspects of Applied Biology 1996;441:29-136.
12. Cardinael R, Mao Z, Chenu C, Hinsinger P. Belowground functioning of agroforestry systems: recent advances and perspectives. Plant Soil 2020;453:1-13.
13. Derpsch R, Goddard T, Zoebisch M, Gan Y, Ellis W, Watson A *et al*. "No-tillage and conservation agriculture: a progress report," in No-Till Farming Systems, World Association of Soil and Water Conservation 2008;3:7-39.
14. Dhaliwal J, Kukal SS, Sharma S. Soil organic carbon stock in relation to aggregate size and stability under treebased cropping systems in Typic Ustochrepts. Agrofor Syst 2018;92:275-284.
15. Dollinger J, Jose S. Agroforestry for soil health. Agroforest Syst. 2018;92:213-219.
16. Germon A, Cardinael R, Prieto I. Unexpected phenology and lifespan of shallow and deep fine trees grown in a silvoarable Mediterranean agroforestry system. Plant Soil 2016;401:409-426. https://doi.org/10.1007 /s11104-015-2753-5
17. Gill AS, Burman D. Production management of field crops in agroforestry systems. In: Recent Advances in Agronomy. (Singh G, Kolar JS & Sekhon HS Eds.) New Delhi, Indian Society of Agronomy 2002, 523-542.
18. Githae EW, Gachene CKK, Njoka JT. Soil physicochemical properties under Acacia senegal varieties in the dryland areas of Kenya. African Journal of Plant Science 2011;5:475-482.
19. Hoosbeek MR, Remme RP, Rusch GM. Trees enhance soil carbon sequestration and nutrient cycling in a silvopastoral system in south-western Nicaragua. Agrofor Syst 2018;92:263-273.
20. Huo G, Zhao X, Gao X, Wang S. Seasonal effects of intercropping on tree water use strategies in semiarid plantations: Evidence from natural and labelling stable isotopes. Plant Soil 2020; https://doi.org/10.1007/s11104-020-04477-5
21. Kulkarni S. Suitability study on *Melia Dubia* based Agroforestry System in North Karnataka. Bull. Env. Pharmacol. Life Sci 2017;6:12:49-52.
22. Kumar K, Laik R, Das DK, Chaturvedi OP. Soil microbial biomass and respiration in afforested calciorthent. Indian Journal of Agroforestry 2008;10(2):75-83.
23. Ling Q, Zhao X, Wu P. Effect of the fodder species canola (*Brassica napus* L.) and daylily (*Hemerocallis fulva* L.) on soil physical properties and soil water content in a rainfed orchard on the semiarid Loess Plateau, China. Plant Soil 2020; https://doi.org/10.1007/s11104-019-04318-0
24. Muchane MN, Sileshi GW, Jonsson M. Agroforestry boosts soil health in the humid and sub-humid tropics: A meta-analysis. Agric Ecosyst Environ 2020;295:106899. https://doi.org/10.1016/j.agee.2020.106899
25. Muthuri C, Bayala J, Iiyama M, Ong C. Trees and micro-climate. In: De Leeuw, J., Njenga, M., Wagner, B., Iiyama, M. (Eds.), Treesilience: An Assessment of the Resilience Provided by Trees in the Drylands of Eastern Africa. World Agroforestry Centre, Nairobi, Kenya 2014;81-85.
26. Nair PKR, Nair VD, Mohan Kumar B, Showalter JM. Carbon sequestration in agroforestry systems. Advances in Agronomy 2010;108:237-307.
27. Noumi VN, Zapfack L, Hamadou MR, Djongmo VA, Witanou N, Nyeck B *et al*. Floristic diversity, carbon storage and ecological services of Eucalyptus agrosystems in Cameroon. Agrofor Syst. 2018;92:239-250.
28. Patel JM, Jaimini SN, Patel SB. Physico-chemical properties of soil under different tree species. Indian Journal of Forestry 2010;33(4):565-568.

29. Pavlidis G, Tsihrintzis VA. Environmental Benefits and Control of Pollution to Surface Water and Groundwater by Agroforestry Systems: a Review. Water Resour Manag 2018. https://doi.org/10.1007/s11269-017-1805-4
30. Pinho RC, Miller RP, Alfaia SS. Agroforestry and the Improvement of Soil Fertility: A View from Amazonia. Applied and Environmental Soil Science. 2012;616383:11.
31. Prasadini P, Sreemannarayana B. Impact of agroforestry systems on nutritional status and biological activity on rainfed red sandy loam soils. Indian Forester 2007;133 (11):1519-1525.
32. Saravanan V, Parthiban KT, Kumar P, Marimuthu. Wood characterization studies on *Melia dubia* Cav. for pulp and paper industry at different age gradation. Research Journal of Recent Sciences 2013;2:183-188.
33. Shin S, Soe KT, Lee H, Kim TH, Lee S, Park MS. A Systematic Map of Agroforestry Research Focusing on Ecosystem Services in the Asia-Pacific Region Forests, 2020;11:368; doi:10.3390/f11040368
34. Shukla A, Kumar A, Chaturvedi OP, Nagori T, Kumar N, Gupta A. Efficacy of rhizobial and phosphate-solubilizing bacteria and arbuscular mycorrhizal fungi to ameliorate shade response on six pulse crops. Agrofor Syst. 2018;92:499-509.
35. Sida TS, Baudron F, Ndoli A. Should fertilizer recommendations be adapted to parkland agroforestry systems? Case studies from Ethiopia and Rwanda. Plant Soil 2020. https://doi.org/10.1007/s11104-019-04271-y
36. Singh NR, Arunachalam A, Devi NP. Soil organic carbon stocks in different agroforestry systems of south Gujarat. Range Mgmt. & Agroforestry 2019;40(1):89-93.
37. Siqueira CCZ, Chiba MK, Moreira RS, Maria TVNA. Carbon stocks of a degraded soil recovered with agroforestry systems. Agroforest Syst 2019.
38. Sirohi C, Bangarwa KS. Effect of different spacings of poplar based agroforestry system on soil chemical properties and nutrient status in Haryana, India. Current Science 2017;113(7):1403-1407.
39. Sto¨cker CM, Bamberg AL, Stumpf L, Monteiro AB, Cardoso JH, Lima ACR. Short-term soil physical quality improvements promoted by an agroforestry system. Agroforest Syst 2020; https://doi.org/10.1007/s10457-020-00524-3.
40. Takimoto A, Nair PKR, Nair VD. Carbon stock and sequestration potential of traditional and improved agroforestry systems in the West African Sahel. Agriculture, Ecosystems and Environment. 2008;125(1-4):159-166.
41. Tewari JC, Ram M, Roy MM, Dagar JC. Livelihood improvements and climate change adaptations through agroforestry in hot arid environments. In: Dagar JC, Singh AK & Arunanchalam J (eds). Agroforestry Systems in India: Livelihood Security and Ecosystem Services. Springer 2013, 155-183.
42. Toky OP, Arya S, Malik K. Effect of environment on nutrient cycling in poplar (*Poplar deltoides*) agroforestry systems in Haryana. Journal of Agrometeorology. 2018;20:282-286.
43. Tsufac AR, Awazi NP, Yerima BPK. Characterization of agroforestry systems and their effectiveness in soil fertility enhancement in the south-west region of Cameroon. Current Research in Environmental Sustainability 2021;3:100024.
44. Udawatta RP, Jose S. Agroforestry strategies to sequester carbon in temperate North America. Agrofor Syst. 2012;86:225-42.
45. Waldron A, Garrity D, Malhi Y, Girardin C, Miller DC, Seddon N. Agroforestry can enhance food security while meeting other sustainable development goals. Trop Conserv Sci. 2017;10:1-6.