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<Review>
토지이용 변화가 깊이별 토양수분에 미치는 영향

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Effects of land use change on soil moisture content at different soil depths

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요 약

토지이용의 변화는 문명이 시작된 이래로 지구 표면을 재설계해온 인류가 유발한 가장 중대한 변화이다. 지난 10년 동안 전 세계적으로 인구가 증가함에 따라 많은 자연림이 경작지로 전환되어 토성이 손상되었다. 시간이 지남에 따라, 이러한 경작지 중 일부는 토양에 주는 피해를 줄이기 위해 조림사업으로 복구되었다. 최근 연구자들은 이러한 토지이용 변화가 토양수분에 어떤 영향을 미치는지 관심을 가지고 연구하고 있는데 이러한 분야에 대한 많은 문헌과 논문이 발간되었지만, 토양수분이 다양한 토지이용의 유형들 사이에서 지표로부터의 깊이에 따라 어떻게 변하는지 논의하는 비판적인 연구는 미미하다. 이 리뷰에서는 자연림, 단일 및 혼합 경작지와 조림지의 토양 깊이에 따른 토양수분의 변동성에 대해 고찰한다. 그 결과 자연림에서 단일 경작지로의 토지이용변화는 표토층의 토양수분 함량을 감소시켰고, 혼합 경작지의 건설은 표토층에서 높은 토양수분 함량을 보이고 깊이에 따라 증가하거나 감소하는 양상을 보였다. 그러나 경작지가 단수림 혹은 과수원으로 그 토지이용이 변화됐을 때는 표토층(0-20 cm)에서 내부 토양층(0-40 cm)까지의 깊이에 따라 토양수분 함량이 감소하였다. 또한, 경작지에서 혼합림으로의 토지이용변화는 30-90 cm 깊이의 토양층에서 극심한 토양수분 함량 감소를 보였다. 이 결과들은 환경 토양수 관리에 필수적인 토양수분을 이해하는 데에 유용할 것이다.

주요어: 토양수분, 단일 경작지, 단일 조림, 혼합 조림, 토지이용 변화

ABSTRACT: Land use is a paramount human-induced change that has redesigned the world's surface since the beginning of civilization. With the worldwide population increment in the last decade, a lot of natural forests have been converted into croplands, which damage soil properties. Over time, some of these established croplands have been transformed into forest plantations to reduce damages to soil properties. Nowadays, scientists are interested on how these land use changes affect soil moisture. Although many studies have been documented in this area, they have not critically studied how soil moisture varies with soil depth between different land use types. In this review, we discuss soil moisture variability with depth in a natural forest, mono- and mixed-croplands, orchard, and mono- and mixed- forest plantations. We observed that the shift in land use from a natural forest into either a mono cropland resulted in the reduction of soil moisture at the topsoil layers, or the establishment of a mixed cropland resulted in high soil moisture at the topsoil layers and the increment and decrease of soil moisture with depth. However, the conversion of cropland to a mono forest or orchard caused soil moisture to decrease with the depth from the top soil layer (0-20 cm) to the inner soil layer (0-40 cm). After the conversion of cropland into a mixed forest, the soil moisture decline was severe in the deeper soil layer of 30-90 cm. This information will be useful in understanding soil moisture, which is essential for the management of environmental soil water.

Key words: soil moisture, mono cropland, mono forest plantation, mixed forest plantation, land use change

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1. Introduction

In a great deal of human history, the earth's surface was uninhabitable and most of its landscapes were covered by forestlands, grasslands, and shrubberies (Hannah and Max, 2019; Awuchi *et al*., 2020; Fazan *et al*., 2020). For the past few centuries, these landscapes have undergone massive changes because of human activities (Sheil, 2018; Liu, C.A. *et al*., 2019; Tuffour-Mills *et al*., 2020; Polizel *et al*., 2021; Rude *et al*., 2021). They have been converted into different land uses, with croplands as the major land use establishment (Zhou *et al*., 2019; Spangler *et al*., 2020; Viana and Rocha, 2020). Before human civilization, there were 60 million square kilometers of natural forest on the earth. Following global development and population growth, a lot of natural forests covering the earth's surface are transformed into croplands. According to FAO. (2020) since the 1990s, about 420 million hectares of natural forest land has been transformed into croplands. Nowadays, there are only less than 40 million square kilometers left in these forests (Bologna and Aquino, 2020). According to Busch and Ferretti-Gallon. (2020) human-driven land use changes from natural forests to cropland, also known as deforestation, is believed to exist where crop products are more profitable. In the context of ecological regions, land use changes in tropical regions (e.g., Amazons) are more dramatic, where natural forest trees are cut down to grow soybeans, corn, and other crops, or to expand pastures (Staal *et al*., 2020). Humans rely strongly on the capacity of these established cropland soils following the clear-cutting of natural forest to maintain a stable crop productivity, which accounts for more than 95% of global crop production needed to feed the expanding world population (Acir and Gunal, 2020; Borrelli *et al*., 2020; Silver *et al*., 2021). However, the transformation of surface land, especially from natural forests to cropland, is a major burden to soil properties in the long run (Cai *et al*., 2019; Xiong *et al*., 2020; Li *et al*., 2021).

Soil naturally exists in a three-phase system of mineral solids, water liquids and gases (Susha *et al*., 2014; Alam *et al*., 2021; Horn, 2021). The maximum amount of water that penetrates the soil profile and then is added to its water phase, and finally stored in different soil layers from the surface soil to the soil layer above the groundwater is called soil moisture (Wenwu *et al*., 2018; Babaeian *et al*., 2019). Knowledge about this amount of seepage water stored in different soil layers (called soil moisture) has been widely used in biogeological and hydro ecological research to monitor croplands, soil behavior, predict severe climate events and manage the environment (Sungmin and Orth, 2021). Soil moisture controls the plant directly by regulating the availability of resources in soils needful for its growth (Yu *et al*., 2015; Wang *et al*., 2019). According to Liu *et al*. (2021) soil moisture is affected by changes in land use and crop cover.

The conversion of a natural forest into cropland is one of humanity's largest impacts on the soil (Haas *et al*., 2020; Yin *et al*., 2020; Wilken *et al*., 2021). A recent assessment indicates that if the current land use change from a natural forest into a cropland trend is persists, approximately 75% of the remaining natural forest will be cleared due to the expansion of cropland establishments in the next 25 to 50 years (Byerlee *et al*., 2014; FAO., 2020). In the past, majority of land use changes from a natural forest into a cropland, involved the cultivation of a mono cropland site whereby farmers grow only single crop yearly, such as wheat, corn, rice, rapeseed, sugar cane, and cotton, a phenomenon known as monocropping (Merten *et al*., 2020; Malaiarasan *et al*., 2021). The establishment of a mono cropland site following deforestation is extensively used in industrial crop cultivation (Bronson, 2019; Salaheen and Biswas, 2019). Also, some mono cropland sites are useful for wastewater treatment and water quality improvement (Marín-Muñiz *et al*., 2020). Another advantage of a mono cropland site is in the improvement of planting productivity and yield increment (Liu *et al*., 2018; Slattery and Ort, 2021). However, some studies show that soil moisture content is reduced after the conversion of natural forests to mono cropland. Bizuhoraho *et al*. (2018) showed that soil moisture was lost upon changing land use from natural forest to cropland. Then, Tellen and Yerima (2018) showed about 23% loss of soil moisture content at low altitude and 42% of soil moisture content loss after change in land use from a natural tropical forest into a mono cropland of corn. Currently land use has drifted to mixed croplands and few studies have started focusing on land use change from a natural forest into a mixed cropland system as separate entities. Results from these studies show that soil moisture either increased or decreased following a change in land use from a natural forest into a mixed cropland, which is contrary to the establishment of a mono cropland after land use change from a natural forest into a mono cropland (NongKling and Kayang, 2017; Chen, C. *et al*., 2019; Whang, J. *et al*., 2021). These discrepancies and uncertainties suggest the need for a study to better understand the pattern of how changing land use from natural forests into mono- and mixed-cropland can impact soil moisture entirely.

In the past decades, many croplands have been converted into either mono or mixed forest plantations (Harper and Sochacki, 2019; Yue *et al*., 2020; Zhou *et al*., 2020; Vincent *et al*., 2021). One of its main purposes is to prevent or repair unhealthy soil, as well as the decline in soil moisture due to land use changing from natural forest to cropland (Yu *et al*., 2019; Ghosh and Mishra, 2020; Jourgholami and Labelle, 2020). At the same time, in some areas, for economic reasons, some croplands have been transformed into orchards (Martin-Gorriz *et al*., 2020; Vu and Shen, 2021; Whang, R. *et al*., 2021). Many research reports point out that the soil moisture content can be improved after land use is switched from a cropland to a forest plantation (Cunningham *et al*., 2015; Cao *et al*., 2018; Vopravil *et al*., 2021). However, it is necessary to report appropriately without any uncertainty how these land use changes from cropland to mono or mixed forest plantation, affect the soil moisture at different soil depths. Soil moisture in different soil layers is usually related to different hydrological processes and ecological functions (Duan *et al*., 2016; Zhang *et al*., 2019; Yang, T. *et al*., 2021).

The soil undergoes a vertical exchange of resources, causing the physical and chemical properties of the soil to change from surface soil to underground soil (Adugna and Abegaz, 2015; Han *et al*., 2018). According to Fang *et al*. (2016) surface soil moisture is usually affected by precipitation and infiltration and is a reliable source of water for crop growth, while deep soil moisture is the soil reservoir. However, most studies only focus on the O layer (0-20 cm) and A layer (0-30 cm) soil depth, and deeper soils are often overlooked or paid less attention. Accurate and continuous measurement of soil moisture with depth can be very difficult, because on-site measurement of moisture in deeper soil layers can be expensive, and there is no direct relationship between surface and underground soil moisture (Gao, L. *et al*., 2015; Gao, X. *et al*., 2017; Yanni *et al*., 2018). Also, another reason may be that the top and subsoil layers are more sensitive to global changes and other disturbances than deeper soil layers (Tian *et al*., 2017; Chen, S. *et al*., 2018; Yanni *et al*., 2018).

Although few studies have been able to report changes in soil moisture content with depth (Tuo *et al*., 2018; Nan *et al*., 2019; Lan *et al*., 2021; Xu *et al*., 2021). For sustainable environmental management, it is necessary to fully understand the changes in soil moisture content with depth between different land use types. Hence, a needful study that reviews the most recent reports on changes in soil moisture content at different land use types and depths. So, the objective of this study was to evaluate recent knowledge on how soil moisture content varies with depth following land use change from a natural forest to into a mono or mixed cropland and then reforestation with either a mono or mixed for-

Table 1. Impact of land use conversion from natural forest to cropland on soil moisture at variable soil depths.

			Mono cropland		
Monocrop land	Climatic Zone/Region	Soil type	Impact	Soil depth (cm)	Reference (s)
Zea mays	Arid	Chernozem	Soil moisture was lower at 0-5 cm and increased from 5-30 cm	0-40	Zhang *et al.* (2016)
Vigna unguiculata	Semiarid	Not Mentioned	0-10 cm soil moisture reduced	0-40	Sadiq *et al.* (2021)
Brachiaria ruziziensis	Tropical hot and humid	Typic Hapludult	0-30 cm high soil moisture	0-60	Silva *et al.* (2020)
			Mixed cropland		
Mixed cropland		Soil type	Impact	Soil depth (cm)	Reference (s)
Senegalia gourmaensis, and *Senegalia dudgeonii*	Tropical savannah (Short Intense rain and long dry season)	Not mentioned	0-5 cm low soil moisture, 5-50 cm, soil moisture increased	0-50	Bayen *et al.* (2020)
Acorus calamus, and *Thalia dealbata*	Subtropical monsoon	Sandy clay	0-10 cm, high soil moisture	0-50	Wang, T. *et al.* (2021)
Zea mays, and *Vigna unguiculata*	Coastal lowland climate (Rainfall from April to December)	Not mentioned	0-10 cm high soil moisture	0-80	Ndiso *et al.* (2017)

est plantation. This information will help broaden our understanding of the impact of land use on soil moisture dynamics in deforestation and reforestation areas between different soil depths and is necessary for proper environmental management and future research.

2. Impact of land use change from a natural forest into a cropland on soil moisture

2.1 Effects of a monocrop land establishment on soil moisture content

Mono cropland sites are highly interactive with soils, and a lot of studies have been done to examine what could be the possible impact of this form of land use on soil (Ahmed *et al*., 2019; Sadiq *et al*., 2021). These studies found out that continuing monocropping for a couple of years can reduce the amount of nutrients in soils (Zhang *et al*., 2016; Salaheen and Biswas, 2019). While studies which focus on the impact of a mono cropland establishment following a change in land use from a natural forest into mono cropland field documented a reduction in surface soil moisture (Table 1). This reduction in the mono cropland top soil's moisture content after land use change from a natural forest can be associated with rapid evaporation of soil water from the crop field's topsoil layer layers due to the reduction in the vegetation cover (Liang *et al*., 2021; Zong *et al*., 2021; Fig. 1). According to Huang *et al*. (2021) the presence of the forest canopy and excessive leave litter on the forest floor, function as shade to the forest floor's topsoil layers, and this serve as a vapor barrier that controls soil moisture lost through evaporation from the topsoil layers but in the mono cropland, the huge canopy or abundant leave litter absent or smaller. The low soil moisture in the top crop fields may also be due to crop planting activities (e.g., ploughing) exposing the arable land to temperature, so the soil moisture quickly evaporates. (Kavian *et al*., 2014; Jeřábek *et al*., 2017). Natural forest soils have high organic matter content, which improves the water absorption and water storage capacity of the soil. However, once mono croplands are established after a natural forest is clear-felled, the soil organic matter will be reduced, and the soil moisture will also be reduced (Tolimir *et al*., 2020).

Although most studies have shown that after land use changes from a natural forest into the mono cropland, the soil moisture in the topsoil of cropland will decrease, the subsoil layers do not follow this pattern. Conversely, the soil moisture content in the subsoil layer (e.g., 40-60 cm) contrasted with the content in the topsoil, is relatively higher (Fig. 1). This can be linked to the fact that the roots density of most crop plants does not grow to the 40-60 cm soil layer, unlike forest trees with deeper root density distribution which absorbs soil moisture from this layer and reduces the soil moisture content (Yu *et al*., 2019; Guo *et al*., 2020). According to Han *et al*. (2018) high soil moisture at this layer could be attributed to a phenomenon called the freeze-thaw cycle, where by soil moisture from deeper soil layers migrate to soil layers above with lower soil temperature, accumulate and render the soil layers below moisture deficient. Also, soil moisture increased with depth (e.g., 0-60 cm) can be attributed to the increase infiltration of soil moisture into deeper soil depths (Sainju *et al*., 2017; Zhao *et al*., 2018; Dai *et al*., 2019).

2.2 Effects of a mixed cropland setting on soil moisture content

For some time now, as an attempt by farmers to resolve the environmental issues and soil nutrient

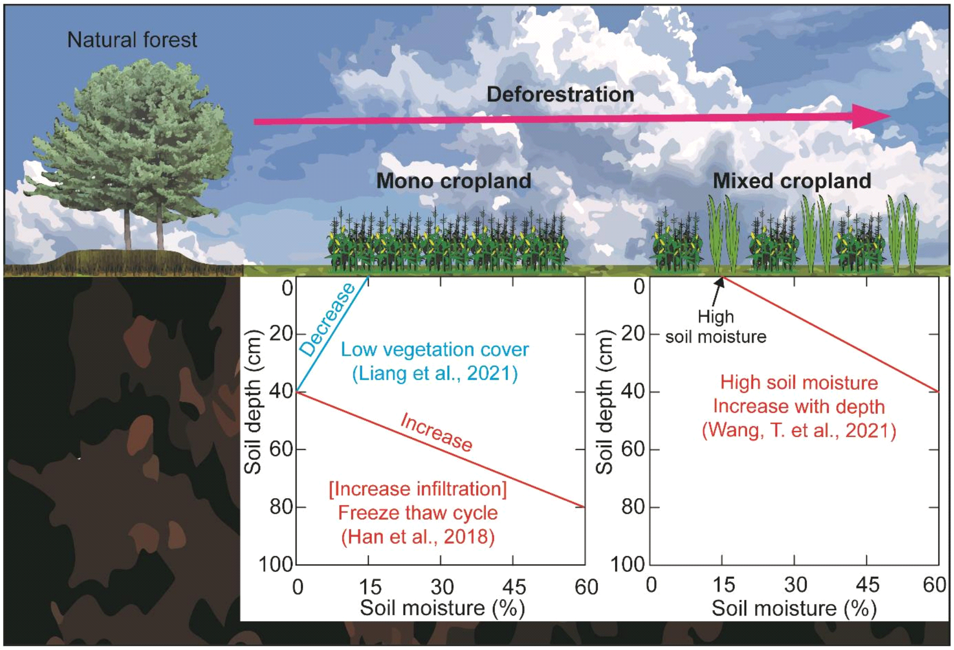

Fig. 1. Land use change from natural forest to mono cropland resulted in the decrease of soil moisture in the 0-40 cm soil layer, and the increase of soil moisture from 40-80 cm to deeper soil moisture but the establishment of a mixed cropland in a native forest resulted to high topsoil moisture that increase with depth.

deficiency, there is a shift from a mono cropland system into a mixed cropping field system (Kordi *et al*., 2020; Schulz *et al*., 2020). A good practical example is in an arid area, where water shortage is a threat to crop cultivation sustainability, and farmers turn to mixed cropping to mitigate this situation (Chen *et al*., 2018a). Mixed cropping, also referred to as intercropping, is the oldest form of systemized agricultural production and involves the growing of two or more species or cultivars of the same species together in the same field (Lizarazo *et al*., 2020). This form of growing crops comes with a lot of advantages such as reduced pest and disease incidence, reduced soil erosion, more biomass production, resource use efficiency, and yield stability (Weltzien and Christinck, 2017; Chen *et al*., 2021).

Recently, a couple of studies have reported high soil moisture at the topsoil layer and an increase in soil moisture with depth following the change in land use from a natural forest into the mixed cropland compared to deforestation from a natural forest into a mono cropland (Wang, T. *et al*., 2021; Table 1). The high amount of soil moisture following intercropping could be associated with more shade from plant leaves and small evapotranspiration (Ndiso *et al*., 2017; Fig. 1). In most cases in a mixed cropping system in the topsoil layer of 0-30 cm, soil moisture turns to be high in the topsoil layer because of a large amount of canopy that lessened the quantity of soil moisture lost through evaporation and the deep system, which helps in the extraction of soil moisture in deeper soil layers and minimized soil water extraction in the topsoil (Nyawade *et al*., 2019; Fig. 1).

3. Impact of land use change from a cropland into a forest plantation on soil moisture

3.1 Effects of a mono forest plantation establishment on soil moisture content

To meet the hydrological international goal of mitigating climate change as stipulated by the "Kyoto Protocol," many croplands have been converted into plantations through investment in the clean development mechanism and reforestation (Hou *et al*., 2019; Bossio *et al*., 2020; Park *et al*., 2020). Even before that, the phenomenon of establishing a mono tree plantation on a cropland can be traced back to the year 1368, when single tree species of *Pinus sylvestris* were cultivated in the Lorenze Forest in Germany and the 18th and 19th centuries in other parts of Europe because of the scarcity of timber, with the aim to enhance the rapid production of plants within a short period (Liu *et al*., 2018; Brooking, 2020; Podrázský *et al*., 2020).

The advantages of converting croplands into a mono forest plantation are restoration of deforested watersheds and destroyed environment (Hong *et al*., 2020; Nichol and Abbs, 2021). When cropland is converted to a mono plantation, in most cases, soil moisture decreases with increasing depth (Fig. 2). The decrease in soil moisture with depth can be linked to the fact that high soil moisture content is absorbed by plant roots at deeper soil layers by the deep root system of trees to be utilized for plant growth and this issue becomes intense as the plant grows older (Jian *et al*., 2015; Liang *et al*., 2018; Zhu *et al*., 2018; Fig. 2). Also, according to Luo *et al*. (2020) the decrease in soil moisture with depth could be associated with the ability of the large forest canopy of mono forest plantations to retain heavy rainfall could penetrate deeper soil layers and light rain with short pulses to only soaked the topsoil.

3.2 Effects of a mixed forest plantation establishment on soil moisture content

As of 2015, following the observation that reforestation with a mono forest plantation comes along with a lot of environmental drawbacks and impacts, about three-quarters of the world's forest industry has shifted to a mixed forest plantation system (e.g., Pinus (42%) and Eucalyptus species (26%) (Marron and Epron, 2019). In this case, mixed forest refers to a plantation reforestation system where two or more tree species are planted in the same area (Tembata *et al*., 2020; Messier *et al*., 2021; Waitz and Sheffer, 2021). The goal of mixed forests is usually achieved by mixing a small number of different tree species or some specific tree species and strains (Lu *et al*., 2018; Branclion and Holl, 2020).

Many studies have documented the positive impact of mixed forest plantations on the environment, but most studies only focus on above-ground environmental factors, and less on underground (Xie *et al*., 2021). Studies on the effects of mixed forest plantation facilities on the properties of underground soil (e.g., soil moisture) indicate that soil moisture decreases with depth after the establishment of a mixed forests (Table 2). The excess deficit or utilization of soil moisture in deeper soil layers and subsequently lower soil moisture in deeper soil layers compared to the shallow depths after the establishment of a mixed forest plantation could be associated to the fact that nearly all mixed tree species consist of deep root systems, which rely more on deeper soil water content for tree growth than the surface soil water (Bello *et al*., 2019). Also, according to Yao *et al*. (2016) the decrease in soil moisture with depth in mixed forests may be related to the obstruction of precipitation (e.g., rainfall) and evaporation, which are due to the excess leaf shade of the plants in the mixed forest.

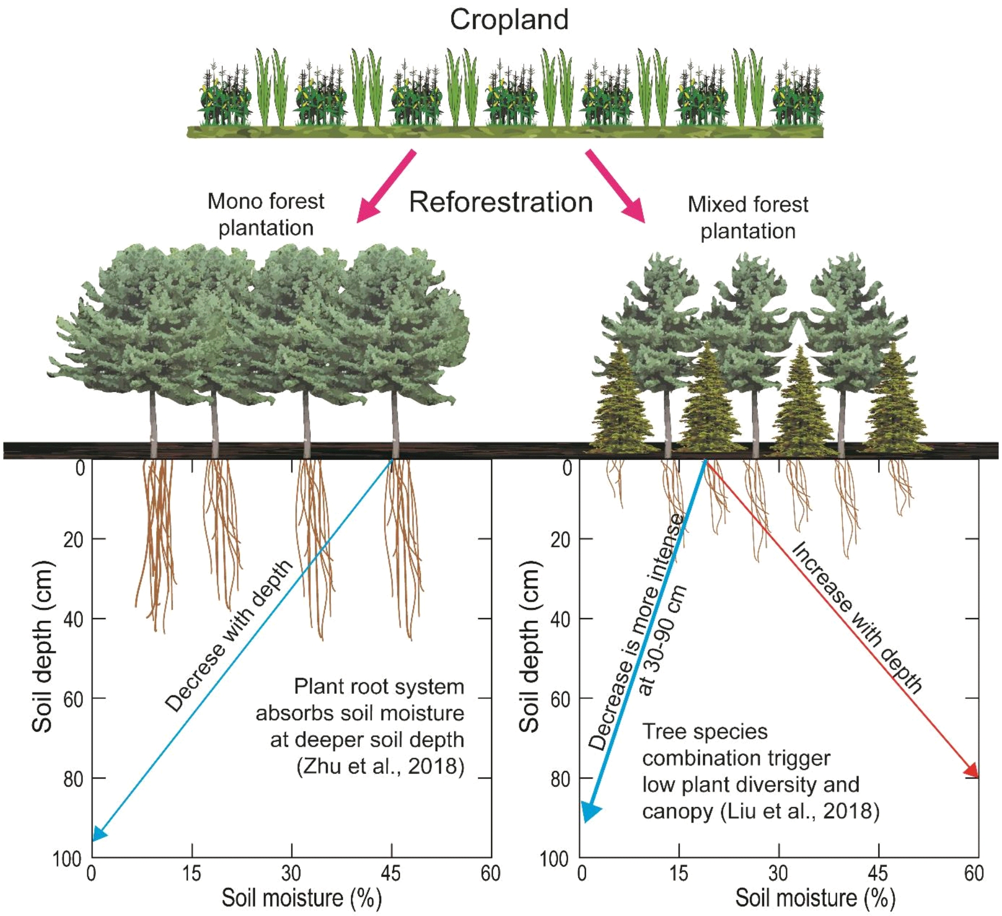

Fig. 2. Land use change from a cropland into a mono forest plantation resulted in the decrease of soil moisture with depth but the shift of land use from a cropland into a mixed forest plantation resulted to an increase and decrease in soil moisture with depth.

Table 2. Effects of land use change from a cropland into a mono/mixed forest plantation on soil moisture at variable soil depths.

			Mono forest plantation		
Mono forest	Climatic Zone/Region	Soil type	Impact	Soil depth (cm)	Reference (s)
Robinia pseudoacacia	Monsoon	loess soil	Soil moisture decreases with depth	0-100	Luo *et al*. (2020)
Robinia pseudoacacia	Monsoon	Luvisol	soil moisture depletion with depth	0-300	Duan *et al*. (2017)
Theobroma cacao L	Tropical	Luvisols Lixisols	Soil moisture increased with depth	0-70	Neither *et al*. (2017)
			Mixed forest plantation		
Mixed forest		Soil type	Impact	Soil depth (cm)	Reference (s)
Eucalyptus and native trees	Tropical	Ultisol	Soil moisture increased with soil depth	0-1,300	Amazonas *et al*. (2018)
Quercus petraea and *Pinus sylvestris*	Temperate	Planosol	30-60 cm intense soil moisture reduction	0-100	Bello *et al*. (2019)
Flemingia macrophylla and *Hevea brasiliensis*	Semiarid	Oxisol	30-90 cm soil moisture declined	0-90	Liu, Z. *et al*. (2019)
Populus spp. and *Pinus sylvestris*	Semiarid	Not mentioned	Soil moisture decreased with depth	0-100	Yao *et al*. (2016)

On the other hand, some studies report that the establishment of mixed forests causes soil moisture to increase with increasing depth. These increase in soil moisture content with depth following the establishment of a mixed forest plantation could be linked to a couple of factors such as the type of tree species used for the establishment of the mixed forest plantation, weather, root system, and diversity of plant communities (Chaturvedi and Raghubanshi, 2018; Maxwell *et al*., 2020; Liu *et al*., 2021; Fig. 2). According to Tang *et al*. (2018) the establishment of mixed forest plantations with tree species such as *Pinus tabuliformis* and *Hippophae rhamnoides* can trigger more soil water use in shallow soil layers than in deeper soil layers. Only when the precipitation in the dry season decreases, can the soil moisture be used in the deeper soil layer (Amazonas *et al*., 2018). In some very rare cases, the mixing of tree species (e.g., *Platanus orientalis* and *Hippophae rhamnoides*) can end up in low tree density and diversity (Liu *et al*., 2018; Fig. 2). According to Gao *et al*. (2018) low plant density results in low transpiration rate, so soil moisture accumulates with increasing depth.

4. Impact of change in land use from cropland into orchards on soil moisture content

In a nutshell, the earth's entire surface is facing soil deterioration which prevails because of the huge augmentation in land use change from natural forest into crop fields (Béliveaua *et al*., 2017; Owuor *et al*., 2018; Fentie *et al*., 2020). In addition to severe soil degradation, land use changes are accompanied by many negative social impacts, such as reduced soil nutrients, low crop productivity, and long-term forest-dependent communities may fall into poverty (Oyetunji *et al*., 2020; Ullah *et al*., 2020). Somehow, to reduce the excessive burden on cropland in some way, since 1990, most of the croplands established on deforested lands have been converted into orchards to produce high-value fruits (Chen, C. *et al*. (2019); Hossain *et al*., 2020). In China, where soils have faced the largest form of soil degradation as erosion caused by land use changed from the natural forest into wheat and maize croplands, in 1990 to 2013 changed croplands into orchards to reduce pressure on crop fields (Lu *et al*., 2016; Chen, Z. *et al*., 2019).

Several studies have shown that as land use is changed from a cropland to an orchard, soil moisture decreases with depth from the top to the bottom soil layer (0-20 cm and 20-40 cm) (Table 3). The decrease of soil moisture from the top to subsoil layers in an orchard field after the conversion of a crop field into an orchard can be attributed to; water infiltration from the top soil layer into the deep soil layers bottom, soil moisture evaporation at the top soil layers and transpiration of the orchard fruit tree (Su and Shangguan, 2019; Tang *et al*., 2019). In addition, the reduction in soil moisture can be attributed to land use treatments, including the use of heavy mechanical tillage in orchards and the application of agrochemicals in orchards (Bogunovic *et al*., 2020; Fig. 3). Some studies have shown that as land use changes from cropland to orchard, soil moisture at a depth of 40-100 cm increases (Table 3). According to Zhang, Z. *et al*. (2018) most orchard fruit trees have long root systems (e.g., *Pyrus communis* orchard*, Malus domestica* orchard). Due to root pressure, this helps to absorb water from deeper soil layers and accumulate them in this underground soil layer (Zhang, Y. *et al*., 2018a; Zhang, J. *et al*., 2018b; Li *et al*., 2019b). In addition, the precipitation water infiltrated from the top soil layer may accumulate in this layer instead of infiltrating into deeper soil layers, which will subsequently increase the soil moisture in this layer. (Zhang *et al*., 2018c; Fig. 3). Soil moisture decreased in the deeper soil layers (e.g., 100-240 cm) (Liu *et al*., 2019b; Fig. 3). The decrease in soil moisture in the deeper soil layer of the orchard field can be attributed to upward migration of soil moisture especially from the water table in this layer to subsoil layers above due to the root pressure of the orchard trees (Song *et al*., 2017; Li *et al*., 2019b).

5. Conclusion and future studies

With the recent human urge to growth, and food deficiencies needed to feed its expanding populations, the earth's surface has experienced an array of land use changes. These land use changes degrade the soil especially soil moisture, which is an important ingredient for ecosystem plant development and proper functioning. The pattern of land use change at first consisted primarily of cutting down natural forest trees to set up mono croplands. As time went by the productivity of these mono croplands dropped. So, in some areas, these mono croplands are converted into mixed croplands, while in other areas for economic reasons, mono croplands are transformed into orchards. Fast forward to the 19th century, with the emergence of climate change and soil degradation mitigation concepts and agenda, most croplands are converted into mono forest plantations and/or mixed forest plantations. Although a lot of studies are done to report how these variable land use

Table 3. Impact of land use change from a cropland into orchard on soil moisture at variable soil depths.

Orchard	Climatic Zone/Region	Impact	Soil type	Soil depth (cm)	Reference (s)
Malus domestica	Semiarid	Soil moistures decline in 100-240 cm	Cumulic Haplustolls	0-600	Liu, Z. *et al*. (2019)
Malus domestica	Semihumid	Soil moisture decreased	Periglacial loess	0-1,800	Zhang *et al*. (2018c)
Malus domestica	Semiarid	40-80 cm Soil moisture reduced	Cumuli-Ustic Isohumosol	0-150	Zhang *et al*. (2017)
Ziziphus jujuba	Temperate semiarid and monsoon	0-100 cm soil moisture reduced	Inceptisols	0-100	Tang *et al*. (2019)
Malus domestica	Subhumid	Soil moisture decrease with depth	Not mentioned	0-600	Zhang and Wang (2018)
Malus domestica	Subhumid	Subsurface soil layer showed a reduction in soil moisture	Malan loess	0-1,000	Li *et al*. (2019a)
Prunus persica	Subtropical	0-10 cm low soil moisture	Silt, Sandy loam	0-30	Sun *et al*. (2019)
Malus domestica	Low annual precipitation zone	0-300 cm soil moisture reduced	Not Mentioned	0-300	Zhang *et al*. (2018b)
Prunus armeniaca	Semiarid	200-300 cm soil moisture reduced	Entisol	0-400	Yang *et al*. (2021a)
Malus domestica	Semiarid	0-8,000 cm soil moisture reduced	Inceptisols	0-8,000	Song *et al*. (2021)

changes impact soil moisture, very few of these studies focus on how these variable land use changes affect soil moisture with depth. So, available studies on land use changes from a natural forest into mono and mixed croplands and then mono- and mixed-forest plantation type on soil moisture with depth in the last decade were selected, inferred and its findings were reported on tables. From the studies, it can be recognized that the transformation of natural forests into mono croplands subjected the soil moisture reduction in the topsoil layers of the mono cropland. However, this was not the case in scenarios whereby natural forests were converted into mixed croplands. The review paper is useful in showing that it is preferable to set up mixed cropland after clearing a natural forest than mono cropland. Establishing mixed cropland increases the soil moisture in the topsoil layer and with depth for a short period of time. Persistent crop cultivation reduces soil nutrients and soil moisture in both mono and mixed croplands. In situations where croplands were converted to orchards mainly for economic reasons, a decrease in soil moisture with depth was noticeable. Soil moisture reduction with depth can only be an issue if the plants in the area (e.g., semiarid regions) depend solely on soil moisture belowground for growth. The reduction of soil moisture with depth can be less severe if the cropland area is converted into a mixed forest plantation instead of mono forest plantations. Heavy rainfall can easily replenish the decrease in soil moisture with depth.

Through this review, it can be noticed that more studies are needed to fill the remaining gaps in this research area. The following studies are necessary to fill this gap;

1) We need more studies on soil mechanisms responsible for soil moisture variability at the top, sub, and deeper soil layers;
2) We need more studies on soil moisture content at deeper soil layers below 100 cm. Most studies of soil moisture variability on croplands only sample the soil layers less than 100 cm. If more studies are done which study soil moisture in soil layers beyond the 100 cm deeper in croplands. This helps to accurately compare the soil moisture variability with depth between the croplands and other land use types which sample beyond the 100 cm soil layer;
3) It will be interesting to compare the changes in soil moisture between a single orchard and a mixed orchard establishment. Most research on measuring soil moisture only focuses on the establishment of a single orchard. Perhaps mixed orchard fruits can increase soil moisture and soil productivity
4) We need more studies to crosscheck how soil

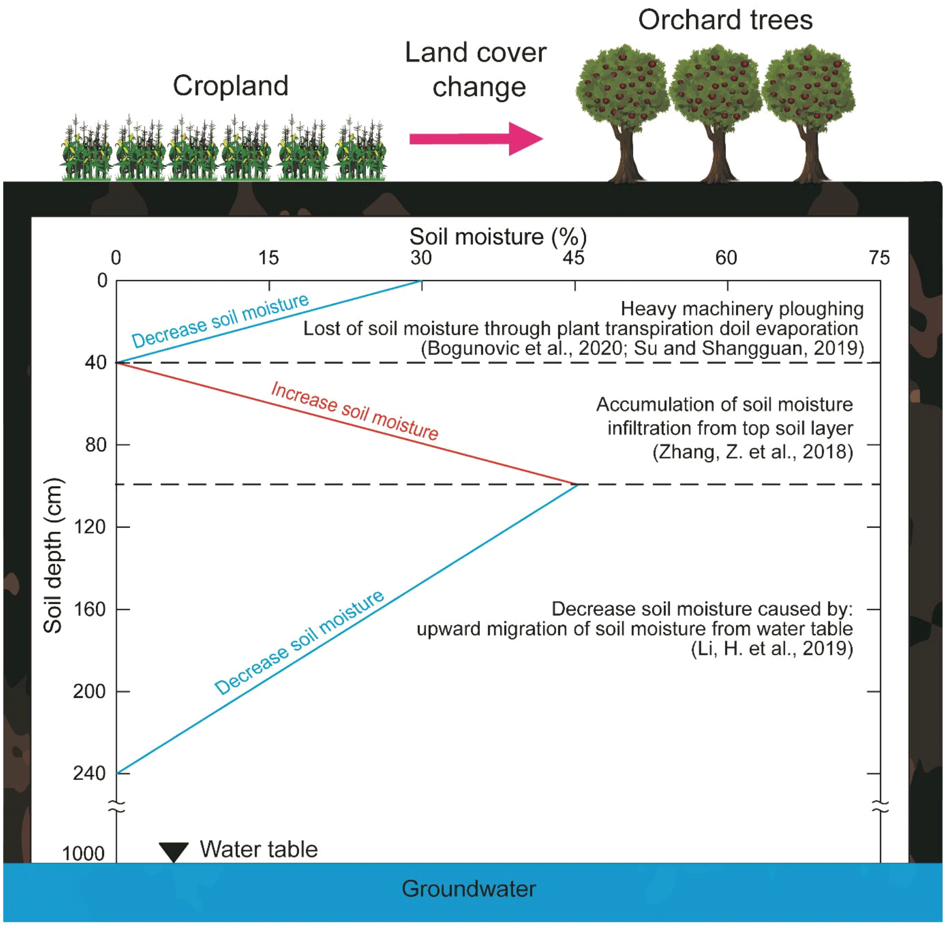

Fig. 3. The shift in land cover from cropland into an orchard resulted in the decrease of soil moisture from the 0-40 cm soil layer, an increase in soil moisture from the 40-100 cm, and a decrease in soil moisture from 100 cm to 240 cm soil layer.

moisture in different soil layers could be replenished through light to heavy precipitations being lost. especially in areas where soil moisture decreases with soil depth; and

5) We need more studies with a more elaborate pattern on how soil moisture varies following the establishment of a mono cropping or mono plantation. These studies show soil moisture is either high or low at the surface and either increase or decreases with depth.

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