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Soil structure impact on soil physics: Concise review of agronomic role

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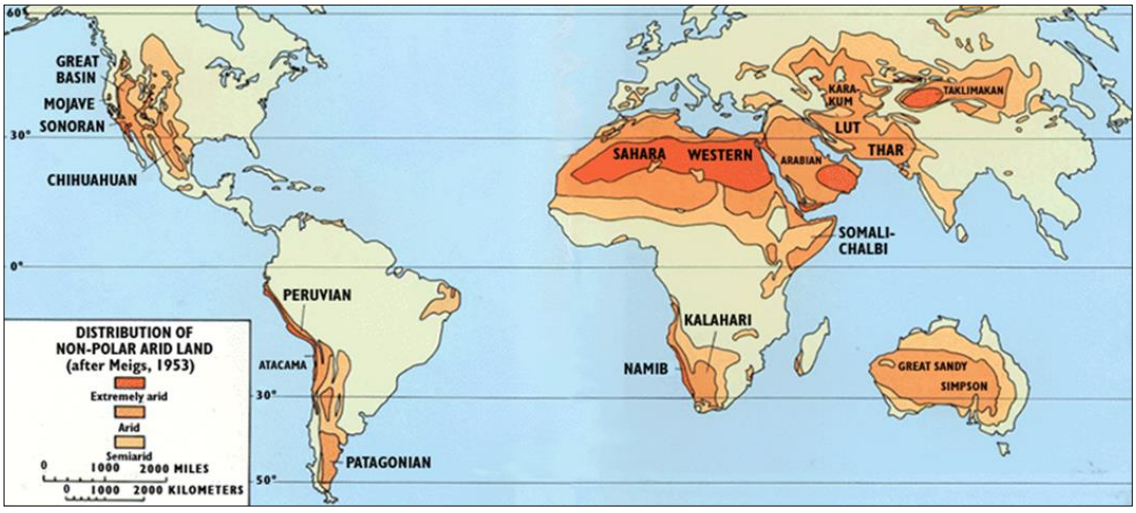
Abstract
Water use efficiency is linked with soil structure stability. Architecture of soil pores and aggregates distribution are fundamental attributes of structure stability. Stable soil structure can improve behavior of organism, air permeability, soil water retention, gas exchange, infiltration, and erosion control, hence, sustain soil productivity for both saturated, near saturated and unsaturated soils. Structure stability is important for agricultural sustainability in agroecosystem soils. This review stats the important of effects of soil structure in relation to soil physics properties on behavior of soil properties and water use efficiency. This study focused on soil management as an important tool for improving soil pores and aggregates. As a conclusion, this review study stated that productivity and water use efficiency of arid land can be improved by improving the stability of soil aggregates and pores, hence, structure stability.

Keywords: soil structure, soil physics, agronomic role

Introduction
The arid lands cover 47% of earth's land surface and 15% of world's population lives in arid and semi-arid regions. Thus, productive lands are finite and represent 11% of earth's land area. Moreover, there has been a big increase in human population. The world's population is more than six billion people increasing at the rate of 1.3% per year and it will be increased by 65% up to year 2050. Thereby, soil degradation is currently becoming a common problem worldwide due to use from a rapidly expanding population which demands an increase in food supply.

Arid and semi-arid zones
Terminologically, arid land, aridity, is a complicated definition because it is related to the place, time and climate conditions. Thereby, the arid land's definition is depending on the location and the purpose of the investigation of the zone under experimental study (Thomas, 2011) [53]. Generally speaking, the arid lands are simply defined as the regions which have water shortage, bad plant growth and scant vegetative areas and the evaporation rate is more than precipitation (Gregorich *et al*., 2001; Maliva and Missimer, 2012) [39]. Accordingly, the arid and semi-arid lands extent almost 26.3% (Koppen, 1931), 30.6% (Thornthwaite, 1948) [54], 32.8% (Heathcote, 1983) [24], 33% (Dregne, 1976) [14], 34.7% (Shantz, 1956) [49], 36.3% (Meigs, 1953) [40], 40% (Parr *et al*., 1990) [47] and 47% (Barakat, 2009) [7] of the global land total area.



***Source*:** https://pubs.usgs.gov/gip/deserts/what/world.html

Fig 1: Geographical distribution of arid lands and its expansion (Meigs, 1953)

Moreover, the area of lands which are good for sustainable crop production is 11-12% from total Earth area and good productive area is 3% of land area of the earth (Aswathanarayana, 1999) [5]. According to Osman (2014) [44] the arable lands are subjected to degradation because of land mismanagement and they noted that the degraded arable lands almost from 30 to 38% (FAO, 2015) [16].
According the statistical data of FAO (2013) [15], the agricultural land area is 28% of total area of the Earth planet. This area is distributed as 30% for crops production and 70% for pasture activities. Only 3% (450 million ha) of agriculture area produces high agricultural production (Fereres and Villalobos, 2016) [17].

Importance of soil physical attributes

Soil is a natural medium for holding water and chemicals for plant growth which consisted of pore spaces, solid minerals particles and organic matters which arising from fauna and flora growth inside soil. Naturally, soil rarely produces a good physical properties condition for enough crop yield and plant growth (Gardner *et al*., 1999) [19]. Soil as a three-phase system is a three dimensional body of the upper layer of Earth's crust. Furthermore, soil is comprised of four components (organic, inorganic, soil solution and soil air) and three phases (soil, liquid and gas) (Lal and Shukla, 2004) [36]. Lal *et al*. (2013) [37] stated that the main attributes of soil are: non-renewable, sensitive to mismanagement and unequal distribution. Blume *et al*. (2010) [9] mentioned that the main functional roles of agricultural soil are control microorganism life, regulation of biogeochemical activities and medium for plant root system growth. Moreover, Soil is crucial for health and life of animal and mankind because it is the major resource of crop production and food resources.
Lal (2013) [37] tabulated the parameters related to soil physical quality which are important for sustainability of agricultural soil. The author itemized the parameters of soil physical quality in four groups: *i*) structure (bulk density, penetrability, shrinkage, texture and organic matter); *ii*) erodibility (texture, aggregation, organic matter and infiltration); *iii*) water transmission (aggregation, drainable macrospores, hydraulic conductivity, bulk density and infiltration) and *iv*) water retention (wilting point, filed capacity, saturation moisture and pore size distribution). Soil physics characterization may be categorized as: *a*) high variable like water flow, mechanical resistance, temperature and soil air; *b*) dynamic properties like aggregates stability, distribution of pore size, density and soil structure; ***c***) relatively stable (minerals, texture and topography) (Blake *et al*., 2008) [8].
Angulo-Jaramillo *et al*., (2000) [3] and Pachepsky and Rawls (2003) [45] summarized the important purposes of hydro-physical characterization in many fields. In agronomy, data of water retention, infiltration, field capacity and welting point for irrigation management. In meteorology, soil surface temperature and soil moisture for calculation heat balance. In hydrology, soil water transport, runoff, infiltration and evapotranspiration. Moreover, in civil engineering, geotechnical properties, slope stability, shear stress and consolidation for foundation engineering (Das, 2016) [12]. Generally, Soil physical quality is so important and sufficient for irrigation systems management because the physical behavior of soil layer concerning the change and control of the movement and mount of water in rootzone of the plants (Nemes, 2011) [42].
In arid zones, Hamza and Anderson (2005) [23]; Moret-Fernández *et al*. (2013) [41] and Indoria *et al*. (2017) [32] reviewed that plant growth, conservation of soil and water and agricultural practices are related to hydrophysical characteristics of soils. Thus, the plant root absorbs water, nutrients and oxygen from soil medium (Foth, 1991) [18]. Therefore, it is important to improve the hydrophysical attributes of soil for maintaining maximum crop production and food at sustainable level. Undoubtedly, for improving the productivity of sandy soil under semi-arid and arid circumstance, it is fundamental to understand the behavior of hydrophysical properties and how to modify soil structure and pore size distribution for developing crop growth and water use efficiency (WUE).

Structure Stability

From a morphological point of view, soil structure is defined as the size, distribution and arrangement of solid particles and pores (Chertkov, 2011) [11]. Furthermore, the term of "soil structure" reflects the case of spatial arrangement, shape and size of solid particles (texture), void spaces and organic and inorganic substances (Almendro-Candel, *et al*., 2018) [2]. Thereby, the soil structure is dynamic property which constituted by the interaction between pore spaces and particles (Gupta *et al*., 1989) [22]. Moreover, soil structure alteration is essential for investigation of hydrophysical properties of soil such as aggregates, porosity, penetration, density, soil water storage and water transmission (Gregorich *et al*., 1993) [20]. Soil structure is the key function of productive soil. Good structure has favorable density, good infiltration, low soil crust, good water retention, high available nutrients and health plant growth. Conversely, weak root elongation, bad plant growth and low crop yield will be occurred because of poor soil structure (Dexter, 1997; Gardner *et al*., 1999) [19].
Moreover, Loch *et al*. (2005) [38] explained that there is important linkage between soil structure and roots system growth, hence, improving water use efficiency (WUE). Jury and Horton (2004) [33] pointed out that soil structure modification by soil management/amendment could be able to change the hydraulic properties, especially, soil water status, flow, storage and retention. Therefore, the behaviors of soil pore network and aggregates stability are sensitive to soil management practices such as amendment, tillage, cropping management and compaction (Ibrahim, 2018; Ibrahim *et al*., 2021; Ibrahim and Horton, 2021) [28, 30]. For adequate understanding the behavior of soil structure and evaluate its changes, structure could be investigated according two crucial perspectives: distribution of pore size and stability aggregates size (Pagliai *et al*., 1998; Six *et al*., 2004) [46, 51]. Good soil structure and imporoved stability/distribution of ag-

gregates are intrinsic qualitative indicators to improved porosity, good firtility, increase crop production and reduce soil erodibility (Bronick and Lal, 2005) [10].

Stability of soil structure can affect the inter-relationship of soil-water-air- root system, significantly. Many studies such as (Bronick and Lal, 2005; Almendro-Candel *et al*., 2018) [10, 2] reported that there is an important impact of soil structure stability on porosity, pores continuity, retain and flow soil water, growth of seedling and root, solute transport, saturated/unsaturated hydraulic conductivity, infiltration, heat transfer, exchange of gas and sustainability of agriculture and environment.

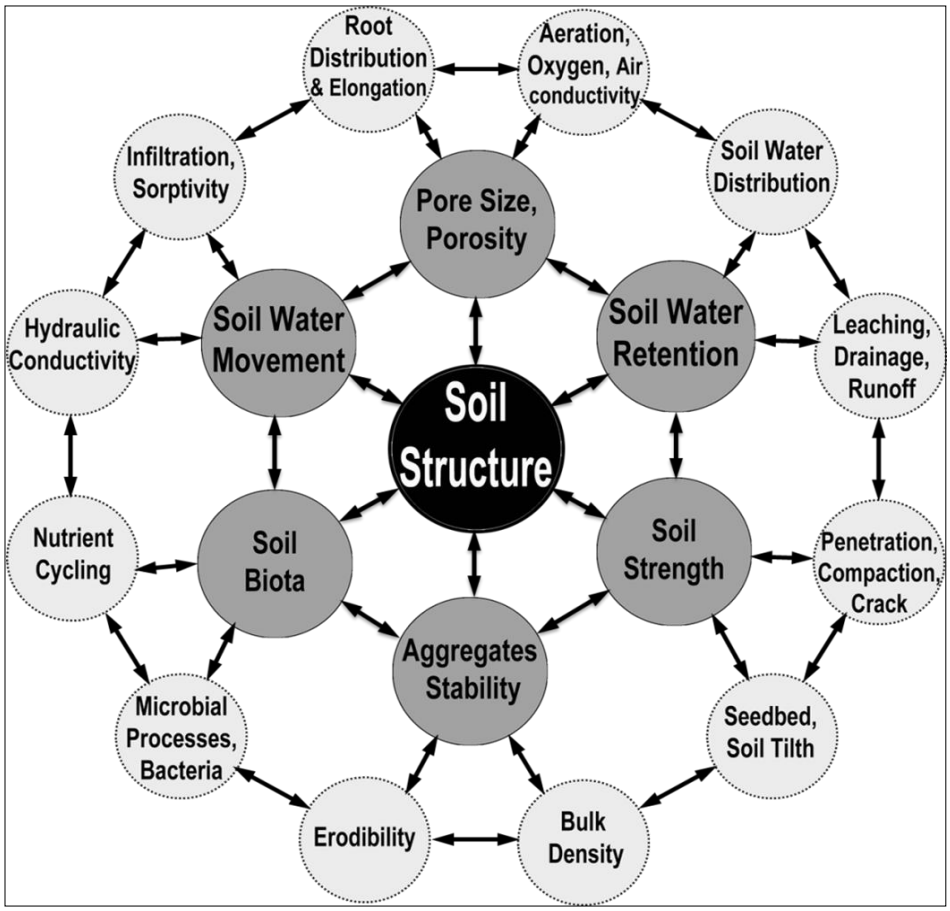


Fig 2: crucial impact of soil structure (Modified from Gardner *et al*., 1999) [19]

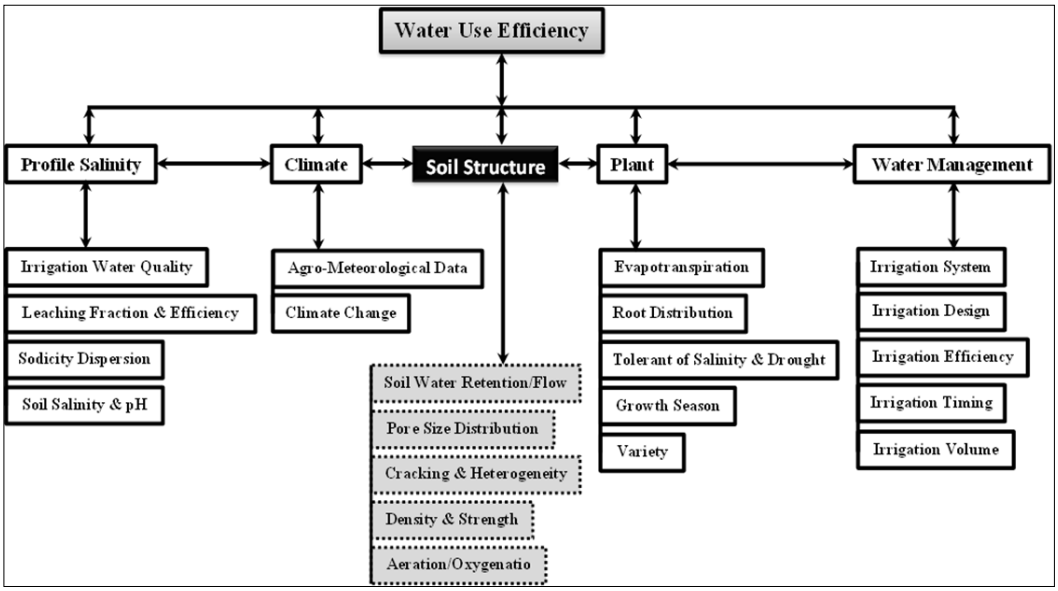


Fig 3: inter-relationship between soil structure, water management, plant, climate, profile salinity and water use efficiency. (Modified from Loch *et al*., 2005) [38]

Soil management

According to edaphological consideration, sandy soil amendment is a type of soil management technique for modifying/changing the structure of soil surface using organic materials (Kay, 1990; Bronick and Lal, 2005) [34, 10]. Thereby, soil structure modification can alter the rearrangement of particles and pores, porosity and hydraulic properties (Horn et al., 2012; Ajayi and Horn, 2016) [25, 1]. The researches of soil organic amendment for improving hydro-physical properties were well documented (Ibrahim et al., 2017; Ibrahim, 2018; Ibrahim and Horton, 2021) [27, 28, 30]. Organic amendment materials are important scenario of soil management for improving stability and formation of macro-aggregates (Six et al., 2004; Yan et al., 2013) [51, 55]. Type and quantity/quality of organic amendment materials are important factors for understanding how to improve size/stability of agricultural soil aggregates (Piccolo, 1996) [48].

Singh et al. (2002) [50] conducted a group of experiments for evaluating the behavior of hydrophysical properties of different types of soil in Odisha state (formerly Orissa, India) and how organic materials affect and change the hydrophysical properties. The authors applied the materials of compost, green manure, molasses, sludge, sawdust, lime and rice straw to soils for trying to improve the productiveity of soil and increase the crops production. Thus, authors stated that the capacity of water retention, aggregate stability and soil water flow were improved. As a consequence of that, the productivity of soil and WUE were increased.

Mixing compost material with agricultural soil improved the formation and stability of macro-aggregates under condition of semi-arid lands (Annabi et al., 2007; Bronick and Lal, 2005) [4, 10]. Thus, erodibility factor (Kerodibility) was decreased by 17% in compost amended soil and the soil losses were decreased by 36% compared to un-amended soil (Tejada and Gonzalez, 2006) [52].

In specific review reported by Hussain et al. (2017) [26], they reviewed that applying biochar to arable soil increased porosity and increased aggregates stability. Obia et al. (2016) [43] conducted a study for evaluating the effects of maize cob biochar on physical properties of sandy loam and loamy sand soils under field conditions of maize and soybeans crops. Under soybeans crop, the soil aggregates stability increased by 4.6 ± 1.9 and 6.8 ± 1.9% for aggregates of 0.6-2 and 2-6 mm respectively. Thus, under maize crop, the stable soil aggregates was increased by 2.6 ± 1.9 and 2.9 ± 1.9% for the 0.6-2 and 2-6 mm aggregates, respectively. Ibrahim (2020) [29] reported that mixing biochar and compost with surface 10-cm layer of sandy soil affected on morphological and chlorophyll attributes of pepper vegetable crops, hence, improve water use efficiency WUE, significantly. Moreover, mismanagement is the main reason of degrading 38% (562 million ha) of total agricultural area in the world and worsening the agricultural crop production was affected by wind/water soil erosion under arid zones (Bai et al., 2016) [6].

Conclusion

In this review study, I have reported the situation of arid land area, role of soil physics properties, Importance of soil structure and soil management. Soil amendment is the most common method for re-modifying soil structure, hence, pores and aggregates. Soil structure is a crucial key function which has significant effects on soil characteristics and water use efficiency. This review concludes:

1. Improving the productivity of soil under arid condition.
2. Soil structure is important for improving water use efficiency WUE.
3. Stability of soil structure is depending on stability, size and distribution of both pores and aggregates.
4. Sandy soils need more strategies for improving sustain productivities.
5. Apply soil amendment materials with varied materials.
6. More future studies are needed for examine the different policies of soil management.
7. More review studies are needed for focusing on different methods of soil structure evaluating.

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