Journal of Environmental Science and Technology 1 (4): 175-180, 2008
ISSN 1994-7887

The Occurrence of Soil Water Repellency Under Different Vegetation and Land Uses in Central Iran

A.A. Zolfaghari and M.A. Hajabbasi
Department of Soil Science, Faculty of Agriculture,
Isfahan University of Technology, Isfahan, Iran

Abstract: The aim of present study was to test water repellency in some arid Iranian soils and to investigate the effect of change in land-use, on water repellent soils. The persistence of soil water repellency was measured on field-moist and dried soil samples by using the Water Drop Penetration Time (WDPT) test in forest, unaltered pastures and cultivated lands of semi-arid regions. Water repellency was observed in forest, but was not observed in pasture and cultivated lands. Water repellency was not found in soil samples containing less than 4.1% organic matter. By increasing soil organic matter, soil water repellency intensity increased, too. Water drop penetration time in samples under the trees was higher than far from trees. Samples with more than 4.3% organic matter were slightly water repellent and samples with more than 4.6% organic matter were strongly water repellent. Generally, in the study area a severely water repellent soil was not found.

Key words: Water repellency, WDPT-test, different vegetation, semi-arid regions

INTRODUCTION

Water repellency may dramatically affect water and solute movement at the field-scale and has often been underestimated (Bauters *et al*., 2000). Water repellency and its spatial variability have been shown to cause no uniform wetting and preferential flow in many soils (Dekker and Ritsema, 1994).

Water repellency of soil surface layers is often recognized in soils that dry out frequently and are not cultivated. When dry, soils resist or retard water infiltration into the matrix (DeBano, 1981; Wallis and Horne, 1992). Water repellent soils can be found in many parts of the world under a variety of climatic conditions and may occupy large areas (Jaramillo *et al*., 2000; Blackwell, 1993). Blackwell (1993) stated that water repellency affects about 5 million ha of agricultural land in sandy districts of Western Australia, South Australia and Victoria. Water repellent soils are also widespread in the Netherlands and occur in sand, loam, clay and peat areas (Dekker and Ritsema, 1994).

Crops and pastures grown on water repellent soils often suffer from poor germination and low yields (Blackwell, 1993; Harper and Gilkes, 1994). The resultant poor plant cover can predispose sandy-surface soils to wind and water erosion (Harper and Gilkes, 1994). Water repellent soils often show irregular moisture patterns, which lead to accelerated transport of water and solutes to the groundwater and surface water (Dekker and Ritsema, 1994). Soil water repellency is generally caused by the presence of organic compounds, such as humic and fulvic acids and fatty waxes, that are able to coat individual soil particles and aggregates (Franco *et al*., 2000). However, intermixing of mineral soil particles with particulate organic material, such as remnants of roots, leaves and stems, may also induce extreme water repellency (Dekker *et al*., 1998).

Several researchers reported the effect of different plant species in contributing water repellency in soils such as citrus trees, perennial pastures (Bond, 1964) heat vegetation and coniferous trees, various chaparral brush species and dry chlorophyll eucalypt forests (Dekker *et al*., 2000). Soil water

Corresponding Author: Ali Asghar Zolfaghari, No. 34, 53 St. Golha Blvd., Tehransar, Zip Code: 13888-83548, Tehran, Iran Tel: +98 21 44526274, +98 912 709 2837 Fax : +98 231 3300412

repellency is also found in grasslands, sports turfs and on golf greens (Dekker *et al*., 2000). The cause of water repellency in sandy soils was found to be an organic coating on the sand grains produced by the growth of fungi (Dekker *et al*., 2000). DeBano (1981) identified a direct contribution of partially decomposed plant parts to development of water repellency in soils.

The authors could not find any published research regarding soil water repellency in Iran. So, the main objective of current study was to test for soil water repellency in some soils of semi-arid regions in the central part of Iran and also to investigate the effect of changing land-use of forest and pastures to agricultural activities, on this phenomenon.

MATERIALS AND METHODS

Description of the Study Area

The study area was located within the northern Karoon watershed in the central Iran (31°11' N and 51°14' E). The study area includes in forest, unaltered pastures and cultivated lands. The prevailing climate of the study area is Mediterranean climate with an altitude of about 2050 m above the sea level. The long term mean annual precipitation was 502 mm. about 83% of the precipitation falls during fall and winter (October to March) and 17% of the precipitation falls during spring (April to June) (Table 1). The study area has a dry summer period.

The forest area is almost 340,000 ha. Forest with a history of at least 20 years in the study area have been fragmented and degraded by such human disturbances as clearance for agriculture and pasture, over harvesting for firewood and overgrazing. Dominant tree species of these sparse forests are *Castaneifolia sativa*. Because of dry moisture regimes in this area, forests of this area do not have dense plant cover like humid areas. Forests are sparse so that the distance between trees is around 4 m. Also forests do not have any natural fire history. Plant cover of long term pastures ranges from 90 to 70% depend on the severity of grazing. Dominant grass species in pasture include *Astragalus* spp. Since 1987, some of these forests have been removed and planted with continuous barley and wheat.

The soil of the study area was classified as Calcic Haploxeralf. Textural class of soils at the 0-5 cm depth were defined as: clay with 300 g kg^{-1} sand, 270 g kg^{-1} and silt 330 g kg^{-1} for the forests (clay loam); with 250 g kg^{-1} sand, 400 g kg^{-1} silt and 350 g kg^{-1} clay for the pasture (clay loam) ; and with 270 g kg^{-1} clay, 400 g kg^{-1} silt and 330 g kg^{-1} sand for the cultivated land (loam) (Table 2).

Soil Sampling

Samples were collected using 100 cm^3 steel cylinders (diameter of 5 cm), two times of the year (January and July in 2006) from forest, pasture and cultivated lands. Samples were collected under the

Table 1: Mean monthly air temperature (°C), precipitation (mm), potential evapotranspiration (mm) and relative humidity (%) in the area during the years 1966-1991

	Jan.	Fab.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Temp.	3.0	4.5	6.0	10.5	14.5	21.0	25.0	24.0	23.0	16.0	9.5	5.5
Prec.	102.6	98.7	73.1	56.1	23.2	2.7	0.2	0.2	0.0	8.3	50.8	86.1
P.Et.	14.9	38.0	60.6	114.5	165.8	212.5	233.5	207.9	169.7	105.8	59.8	24.5
RH	65.0	62.0	59.0	50.0	39.0	21.0	30.0	30.0	31.0	42.0	53.0	63.0

*Temp: Temperature, Prec.: Precipitation, P.ET: Potential Evapotranspiration and RH: Relative Humidity

Table 2: Some soil physical and chemical properties of the experiment site

	Treatments*				
Land uses	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (dS m^{-1})	EC (dS m^{-1})	pH
Forest	270	330	300	0.58	8.1
Pasture	250	400	350	0.51	7.7
Cultivated	270	400	330	0.67	8.0

tree canopies and outside the tree canopies (the interspaces between tree canopies approximately 2 m away from each tree) in the forest land. Seventy two samples were taken from each site (forest, pasture and cultivated lands), at depths 0-5 and 5-10 cm. In forest, 36 samples were taken from within the tree canopies and thirty six samples from outside the tree canopies. First of all, soils were collected in the field and actual water repellency was tested immediately following field collection. Then, the samples were taken dried at 40°C for 5 days and the potential water repellency was measured. Also, disturbed samples were collected separately for determining organic matter and particle size distribution, in a same manner.

Laboratory and Data Analyses

Soil water repellency was determined in this study with the empirical Water Drop Penetration Time (WDPT) test described by several researchers (Letey *et al*., 2000). Three drops of distilled water from a standard medicine dropper were placed on the smoothed surface of a soil sample and the time that elapsed before the drops were absorbed was determined. Using the WDPT test on dried samples in the laboratory gives the persistence of potential water repellency while its use on field-moist samples yields the actual water repellency (Dekker and Ritsema, 1994). Different classification systems for water repellency are used (Dekker, 1998). Based on penetration time, soil is considered wettable (less than 5-10 sec), slightly water repellent (5-60 sec), strongly water repellent (60-600 sec), severely water repellent (600-3600 sec) and extremely water repellent (more than 3600 sec).

Particle size distribution and soil organic carbon were determined using disturbed soil samples sieved through a 2 mm by Bouyoucos hydrometer method (Bouyoucos, 1962) and modified Walkey-Black wet oxidation procedure, respectively. Multiplying the soil organic carbon by 1.72 resulted in the SOM (Nelson and Sommers, 1982).

RESULTS AND DISCUSSION

Water Drop Penetration Time

Actual water repellency (i.e., those measured at field moisture contents) was found in soils collected on two of the sixteen combinations of land use-season-depth samples (Table 3). Potential water repellency (i.e., that measured after laboratory drying) was present in two other additional samples. All samples that were water repellent were found within upper soil layer (0-5 cm) within the forest canopy or in outside the tree canopies. All water repellent samples contained organic matter contents greater than 4.1%. In general the water repellency increased with increasing soil organic matter content and the soil samples collected under trees had higher degree of water repellency than those collected outside the tree canopies. For example, the average actual water repellency under the tree canopies was 220 sec compared to 170 sec on the outside the tree canopies sites. Water repellency was not detected in the deeper soil layer (i.e., 5-10 cm) in the forest or at any soil depth in the soils under pasture or that was cultivated. In arid regions water repellency is commonly found in surface layers (Jaramillo *et al*., 2000) as contrasted to more humid climates (e.g., the Netherlands) where water repellency can be found as deep as 45 cm beneath the soil surface (Dekker and Ritsema, 1994).

Neither potential nor actual water repellency was found in the soils collected in pastures or in cultivated areas (Table 3). The lack of water repellency in these grass and cultivated areas may have occurred for a couple reasons. First, the amounts of soil organic matter under grass or crops were generally much lower than those found in the surface soils collected from the forested sites. The organic matter of all the grass and pasture samples was less than 4%. The lower soil matter may have occurred because it was removed either by livestock or used for human consumption. Also higher erosion rates,

Table 3: Actual and potential water repellency measured in January and July 2006 in the forest, pasture and cultivated lands

							Actual and potential water repellency (percentage of samples)							
							<5 sec		5-60 sec		60-600 sec		600-3600 sec	
Land uses	Vegetation	Date	Soil texture	Depth (cm)	n	OM* (%)	Act	Pot	Act	Pot	Act	Pot	Act	Pot
Forest	*Castaneifolia*	Jan.	Clay loam	0-5	72	6.50	100	---	---	15	---	85	---	---
(tree canopy)	*sativa*		Clay loam	5-10	72	4.10	100	100	---	---	---	---	---	---
		Jul.	Clay loam	0-5	72	6.50	---	---	5	2	95	98	---	---
			Clay loam	5-10	72	4.10	100	100	---	---	---	---	---	---
Forest	*Castaneifolia*	Jan.	Clay loam	0-5	72	5.70	100	---	---	25	---	75	---	---
(outside	*sativa*		Clay loam	5-10	72	3.90	100	100	---	---	---	---	---	---
the tree		Jul.	Clay loam	0-5	72	5.70	---	---	25	20	75	80	---	---
canopy)			Clay loam	5-10	72	3.90	100	100	---	---	---	---	---	---
Pasture	*Astragalus*	Jan.	Clay loam	0-5	72	3.35	100	100	---	---	---	---	---	---
	spp.		Clay loam	5-10	72	2.93	100	100	---	---	---	---	---	---
		Jul.	Clay loam	0-5	72	3.35	100	100	---	---	---	---	---	---
			Clay loam	5-10	72	2.93	100	100	---	---	---	---	---	---
Cultivated	Barley and	Jan.	Loam	0-5	72	3.02	100	100	---	---	---	---	---	---
	wheat		Clay loam	5-10	72	2.40	100	100	---	---	---	---	---	---
		Jul.	Loam	0-5	72	3.02	100	100	---	---	---	---	---	---
			Clay loam	5-10	72	2.40	100	100	---	---	---	---	---	---

*OM (%): Average Organic Matter content in samples (%)

particularly from the cultivated areas, also have a resulted in the removal of the surface organic matter. A second factor is that the type of organic matter produced by trees may have a greater potential for producing water repellency than organic matter produced under grasses and cultivated crops.

Soil moisture affected potential and actual soil water repellency (Table 3). For example, actual water repellency was not observed in the samples collected in January on forested sites when soil water content reached 20-22%. In contrast, water content was only about 5% in July and water repellency was measured in both of the upper soil layers collected from the forested sites. Potential water repellency was present in all four surface soils collected on the forested sites in both January and July because all the samples had been dried in the laboratory prior to testing for water repellency. Soil texture did not appear as an effective factor on water repellency in this study since all soils studied had similar amounts of clay and sand (Table 2). Previous studies in more humid environments have shown clay content to affect water repellency (Dekker, 1998).

The long-term annual precipitation data show that, first rainfall occurs usually in October (Table 1). Prior to this time, soil evapotranspiration potential is high and the soil is dry thus water repellency is also high. Therefore the first rainfall has the potential to produce intense runoff in the forest.

The occurrence of fire is often associated with water repellency (both potential and actual). However, at our sites there was no evidence of natural fire history.

Organic Matter Content and Potential Water Repellency

As shown in Fig. 1 the positive relationship between organic matter content and persistence of potential water repellency of samples collected from topsoil of the forest is evident. A linear regression model using the soil of organic matter variable as possible predictor of potential water repellency, was tested. Organic matter was a significant ($\alpha<0.01$) predictor of potential water repellency:

$$WDPT = 98.4\ OM\% - 388.37$$

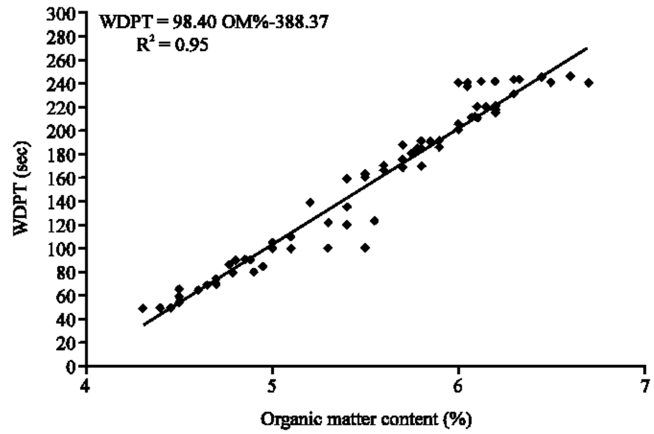

Fig. 1: Relationship between the organic matter content and the WDPT value of samples (n = 72) taken in the forest

According to Harper *et al.* (2000), accumulation of sufficient amounts of organic matter can induce water repellency in any soil and water repellency increases in severity with increasing organic matter content. In this study soil samples with 4.1-4.6% organic matter were slightly water repellent and samples with more than 4.6% organic matter were strongly water repellent. In this region, soil samples with severe water repellency were not found.

CONCLUSIONS

This study reports the first documented occurrence of water repellency in Iran. Although, it is a case study, it does in general agree with and confirm some of the previously-defined relationships of vegetation, soil organic matter and soil depth with water repellency. The results also demonstrate differences between potential and actual soil water repellency that are gaining critical when evaluating water repellency in arid regions. There was a strong relationship between potential water repellency and percentage organic matter in surface soils under forested areas. Changes in land-use induced negative effects on water repellency; however, it is not necessary true. Water repellency was not present in the grassland and cultivation management systems of central Iran and is related in part to the low levels of organic matter found in these systems. This of course can not be generalized because some of the first published articles on non-fire water repellency (Bond, 1964) were from studies conducted on grasslands.

REFERENCES

Bauters, T.W.J., T.S. Steenhuis, D.A. DiCarlo, J.L. Nieber, L.W. Dekker, C.J. Ritsema, J.Y. Parlange and R. Haverkamp, 2000. Physics of water repellent soils. J. Hydrol., 231/232: 233-234.

Blackwell, P., 1993. Improving sustainable production from water repellent sands. J. Agric. W. Aust., 34: 160-167.

Bond, R.D., 1964. The influence of the microflora on the physical properties of soils. Field studies on water repellent sands. Aust. J. Soil Res., 2: 123-131.

Bouyoucos, G.J., 1962. Hydrometer method improved for making particle size analysis of soils. Agron. J., 54: 464-465.

DeBano, L. F., 1981. Water repellent soils: A state of the art. USDA Forest Service General Technical Report. PS W-46. Berkeley, California, pp: 21 http://www.amazon.com/Water-repellent-soils-state-art/dp/B0006XY7LE/ref=sr_1_6?ie=UTF8&s=books&qid=1214469496&sr=1-6

Dekker, L.W. and C.J. Ritsema, 1994. How water moves in a water repellent sandy soil. 1. Potential and actual water repellency. Water. Resour. Res., 30: 2507-2517.

Dekker, L.W., 1998. Moisture variability resulting from water repellency in Dutch soils. Ph.D Thesis, Wageningen Agricultural University, The Netherlands. http://library.wur.nl/wda/abstracts/ab2467.html.

Dekker, L.W., J. Cone, C.J. Ritsema, K. Oostindie and H. Boersma, 1998. Effect of drying temperature on the severity of soil water repellency. Soil Sci., 163: 780-796.

Dekker, L.W., P.D. Jungrius and K. Oostindie, 2000. Extent and significance of water repellency in dunes along the Dutch coast. J. Hydrol. 231/232: 112-125.

Franco, C.M.M., P.J. Clarke and J.M. Oades, 2000. Hydrophobic properties and chemical characterization of natural water repellent materials in Australian sands. J. Hydrol., 231/232: 47-58.

Harper, R.J. and R.J. Gilkes, 1994. Soil attributes related to water repellency and the utility of soil survey for predicting its occurrence. Aust. J. Soil Res., 32: 1109-1124.

Harper, R.J., I. Mckissock, R.J. Gilkes, D.J. Cater and P.S. Blackwell, 2000. A multivariate framework for interpreting the effects of soil properties, soil management and land use on water repellency. J. Hydrol., 231/232: 371-383.

Jaramillo, D.F., L.W. Dekker, C.J. Ritsema and J.M.H. Hendrickx, 2000. Occurrence of soil water repellency in arid and humid climates. J. Hydrol., 231/232: 105-111.

Letey, J., M.L.K. Carrillo and X.P. Pange, 2000. Approaches to characterize the degree of water repellency. J. Hydrol., 231/232: 61-65.

Nelson, D.W. and L.E. Sommers, 1982. Total Carbon, Organic Carbon and Organic Matter. In: Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties, Page, A.L. (Ed.). Agron. Monogr., 9. ASA-SSA, Madison, WI, ISBN: 0-89118-072-2 pp: 539–579.

Wallis, M.G., and D.J. Horne, 1992. Soil water repellency. Adv. Soil Sci., 20: 91-141.