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Using Apparent Soil Electrical Conductivity to Improve Agricultural Yield in Iran

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Abstract: Iran is one of the most popular countries in the Middle East and the huge amount of population needs a great deal of food. Some problems of Iran agriculture were discussed in the study. Iran has saline soil, dry climate and high climatic variation in different regions. For these reasons, Iranian farmers must be able to produce food not only for native people but also for the other people of the world enabling them to compete with the foreign farmers. For having a sustainable agriculture it is needed to know the soil characteristics, shortages and abilities. Apparent soil electrical conductivity was used for field scale application for measuring soil salinity, cation exchange capacity, soil water content and soil temperature. Apparent soil electrical conductivity is a quick, reliable and easy-to-take soil measurement than often relates to crop yield. Therefore, measurement of EC_a is a frequently used tool in precision agriculture research that can improve agricultural yield.

Key word: Apparent soil electrical conductivity, climate, Iran, precision agriculture, soil

INTRODUCTION

Dry climate, salt-rich parent materials of soil formation, insufficient drainage and saline groundwater or irrigation water are the main causes of salt accumulation in Iran soils. About 75% of the total land area (1,648,000 km^2) is semi-arid or arid. While the average annual rainfall is at 252 mm, 66% of the country receives less than 250 mm of precipitation (FAO, 2000). Potential evaporation is generally high ranging from 500 to 4000 mm.year^{-1}. Strong winds that blow for instance across the Central Plateau, the lack of precipitation and excessive evaporation (Fig. 1) might redistribute salts from salt-crusted desert areas onto the surfaces of soils. The salts originate from evaporitic rocks covering large areas in southern and Central Iran (Kehl, 2006). These conditions made a lot of problems for Iranian farmers to have satisfiable yield. In this situation, farmers must use precision agriculture techniques. Having suitable information about the soil characteristics can have an important rule in precision agriculture. Farmers practicing precision agriculture can now collect more detailed information about the spatial characteristics of their farming operations than ever before. In addition to yield, boundary and field attribute maps, new electronic, mechanical, and chemical sensors are being developed to measure and map many soil and plant properties. Soil EC is one of the simplest, least expensive soil measurements available to precision farmers today. Soil EC measurement can provide more measurements in a shorter amount of time than traditional grid soil sampling (Grisso *et al.*, 2007).

Iran soil condition: Mineralized runoff from channel, sheet and groundwater flow dissipates into saline marshes, salt flats and salt crusted playas, where salts accumulate by evaporation of stagnant surface water or groundwater occurring close to the land surface. These salt-rich areas cover vast depressions of the Central Plateau. Bordering these depressions large areas are covered by weakly to strongly saline soils (Fig. 1). In interior basin, intrusion of saline groundwater might also be caused by excessive groundwater extraction for irrigation purposes. In an early countrywide assessment, Dewan and Famouri (1964) estimated the extent of saline soils in Iran at about 25 Mio ha including saline alluvial soils, Solonchak and Solonetz, salt marsh soils and saline desert soils. According to the recently published soil map at the scale of 1:1,000,000 (SWRI, 2000) slightly and moderately saline soils occupy approximately 25.5 Mio ha and strongly saline soils cover about 8.5 Mio ha (FAO, 2000). Large areas covered by saline soils are not used for agricultural purposes because of water shortage particularly in the Central Plateau. Arable land covers 10% of the total land area of Iran (1,648,195 km^2), while 27 and 11% are covered by pasture and forest, respectively. The extent of arable land is limited by the availability of water (Ghassemi *et al.*, 1995), and could be considerably increased, if water storage and distribution would be improved. Today, about 46% of arable land (7.3 Mio ha) is irrigated (FAO, 2005) producing about 90% of agricultural crops in Iran (Siadat, 1998). Agricultural purposes consumed 91.6% of the annual water demand (70 km^3 in 1993, FAO 2000). The country thus heavily depends on effective and sustainable irrigation practices.

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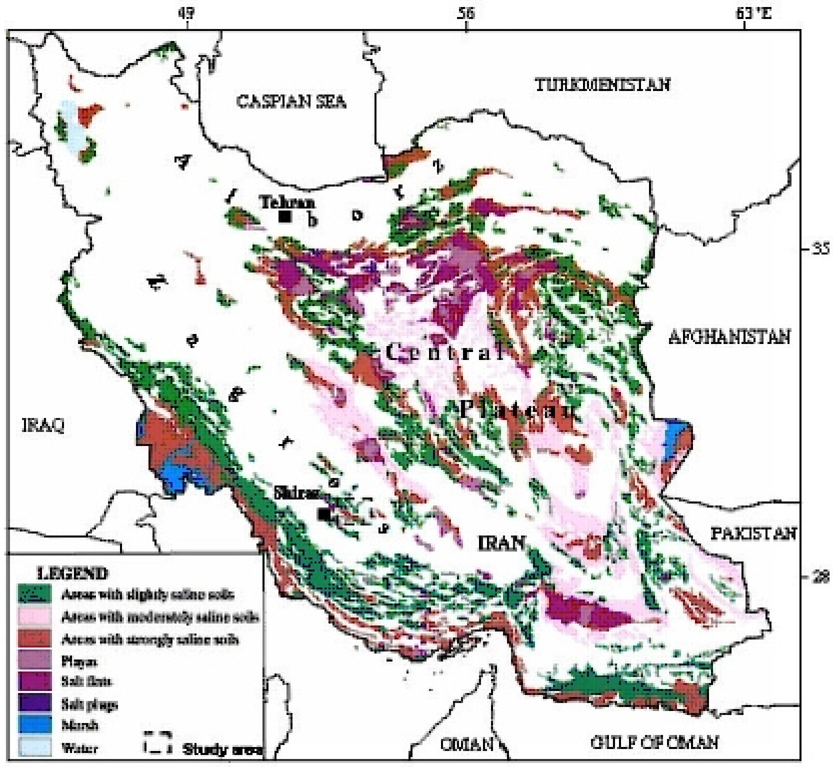

Fig. 1: Distribution of salt-affected soils in Iran (SWRI 2000, changed)

In many areas primarily salt-affected soils are irrigated. In addition, irrigation often causes secondary soil salinization depending on a variety of factors including the salt content and composition of irrigation waters, distance to ground water table raised by excessive irrigation and conveyance losses and insufficient drainage or water scarcity hampering effective leaching. According to estimates for 1997, secondary salinization affected 28% or 2.7 Mio ha of irrigated lands and also occurred on 0.6 Mio ha in rain-fed areas (FAO, 2000). For the year 1974, 38% of irrigated lands were likely affected by secondary salinization and water logging (Ghassemi *et al*., 1995). A systematic study on the extent of secondary salinization in Iran is still missing (Ghassemi *et al*., 1995), and data on salinization-related yield decreases or on the abandonment of agricultural fields and desertification is scarce. Nevertheless, the problem of secondary salinization is being faced. Prevention strategies focus on increasing the water use efficiency in irrigated agriculture, which is probably as low as 30%, as a consequence of 60% conveyance efficiency and 50% application efficiency (Siadat, 1998).

RESULTS AND DISCUSSION

Distribution of different climatic conditions in Iran: In Table 1 (Jihad Agricultural Ministry, 2007) the climatic distribution in Iran provinces is shown. From this table, it can be seen that the main part of many provinces has ultra to semi arid climate that is inappropriate for a productive agriculture. Charmahalobakhtiri, Mazandaran and Gilan with highest humid areas are the most suitable provinces in Iran for agriculture. From this Table 2 (Jihad Agricultural Ministry, 2007), it can be seen that the major climate in 13 provinces is arid climate that hinders farmers to have suitable yield. In this condition the best suggestion for farmers to keep yield in a high level, is using precision agriculture techniques. Measuring of apparent soil electrical conductivity is one of the easiest ways to obtain useful information about soil characteristics, which have a vital rule in precision agriculture.

EC measurement in soil: Electrical Conductivity (EC) is the ability of a material to transmit (conduct) an electrical current and is commonly expressed in units of milliSiemens per meter ($mS.m^{-1}$). Soil EC measurements may also be reported in units of deciSiemens per meter ($dS.m^{-1}$), which is equal to the reading in $mS.m^{-1}$ divided by 100.

Factors affecting soil EC: The conduction of electricity in soils takes place through the moisture-filled pores that occur between individual soil particles. Therefore, the EC

Table 1: The division of different climatic condition percentage in Iran provinces

No.	Climate / Province	Ultra-Arid (1)	Arid (2)	Semi-arid (3)	Mediterranean (4)	Semi-Humid (5)	Humid (6)	Ultra-Humid (7)
1	Markazi	00.00	31.59	59.99	08.13	00.22	03.06	00.00
2	Gilan	00.00	02.64	03.71	02.15	09.47	17.40	53.12
3	Mazandaran	00.00	00.00	01.4	13.28	16.83	27.77	43.31
4	Golestan	00.00	18.94	43.55	08.80	07.52	12.29	08.88
5	Ardebil	00.00	00.15	51.92	20.14	11.64	12.10	04.06
6	Northern Azerbayejan	00.00	01.48	52.66	18.72	16.56	07.85	02.74
7	Southern Azerbayejan	00.00	00.68	46.59	16.82	09.14	16.43	10.36
8	Kermanshah	00.00	05.45	36.27	17.66	12.37	22.50	05.76
9	Khoozestan	17.56	48.03	19.22	04.64	04.02	04.82	01.68
10	Fars	04.31	43.32	38.77	06.63	02.85	02.67	00.23
11	Kerman	56.48	33.78	06.72	02.03	00.39	00.04	00.00
12	Khorasan	35.59	39.70	21.45	02.12	00.61	00.45	00.08
13	Esfahan	61.15	21.78	07.92	02.98	01.46	00.81	02.29
14	Hormozgan	33.64	65.76	00.46	00.15	00.00	00.00	00.00
15	Sistan baloochestan	73.76	25.70	00.07	00.00	00.00	00.00	00.00
16	Kordestan	00.00	00.00	23.70	27.10	20.22	25.55	03.42
17	Hamedan	00.00	00.00	73.47	16.18	04.71	03.80	01.21
18	Lorestan	00.00	00.00	35.79	18.29	12.39	15.14	18.39
19	Ilam	00.00	40.21	43.38	11.68	04.73	00.00	00.00
20	Zanjan	00.00	01.69	70.33	19.32	05.81	02.58	00.27
21	Ghazvin	00.00	20.07	53.14	14.57	08.27	02.44	01.51
22	Charmahalobakhtiri	00.00	00.74	16.85	13.56	14.06	14.69	40.11
23	Kohkilooye va Boyerahmad	00.00	00.25	27.01	15.76	30.02	19.11	07.86
24	Semnan	59.86	28.63	06.04	01.60	01.88	01.11	00.82
25	Yazd	83.90	13.50	02.51	00.00	00.00	00.00	00.00
26	Booshehr	03.02	82.26	14.69	00.00	00.00	00.00	00.00
27	Ghome	38.93	51.02	05.82	00.01	00.00	00.00	00.00
28	Tehran	00.00	33.17	20.11	06.40	06.91	12.68	19.99

Table 2: Summary of Iran climatic condition

Climates	Percentage area	Considerations
Ultra arid	30.4	The major climate in 5 provinces
Arid	29.0	The major climate in 7 provinces
Semi arid	19.0	The major climate in 11 provinces
Mediterranean	05.0	The major climate in 2 provinces
Semi humid	5/3	___________________
Humid	6/3	___________________
Ultra humid	05.0	The major climate in 3 provinces

of soil is influenced by interactions among the following soil properties (Doerge, 1999):

Pore continuity: Soils with water-filled pore spaces that are connected directly with neighboring soil pores tend to conduct electricity more readily. Soils with high clay content have numerous, small water-filled pores that are quite continuous and usually conduct electricity better than sandier soils. Curiously, compaction will normally increase soil EC.

Water content: Dry soils are much lower in conductivity than moist soils.

Salinity level: Increasing concentration of electrolytes (salts) in soil water will dramatically increase soil EC. The salinity level in the soils of most humid regions such as the Corn Belt is normally very low. However there are areas that are affected by Ca, Mg, chloride (Cl), sulfate (SO_4), or other salts that will have elevated EC levels.

Cation exchange capacity: Mineral soils containing high levels of O.M. (humus) and/or 2:1 clay minerals such as montmorillonite, illite or vermiculite have a much higher ability to retain positively charged ions...such as Ca, Mg, potassium (K), sodium (Na), ammonium (NH_4), or hydrogen (H) than soils lacking these constituents. The presence of these ions in the moisture-filled soil pores will enhance soil EC in the same way that salinity does.

Depth: The signal strength of EC measurements decreases with soil depth. Therefore, subsurface features will not be expressed as intensely by EC mapping as the same feature if it were located nearer to the soil surface.

Temperature: As temperature decreases toward the freezing point of water, soil EC decreases slightly. Below freezing, soil pores become increasingly insulated from each other and overall soil EC declines rapidly.

Sensor types for measuring soil EC: There are two types of sensors commercially available to measure soil EC in the field. Sensor types are contact or non-contact. Measurements by both sensor types have given comparable results (Grisso *et al.*, 2007).

Contact sensor measurements: This type of sensor uses coulters as electrodes to make contact with the soil and to measure the electrical conductivity. In this approach, two to three pairs of coulters are mounted on a toolbar; one

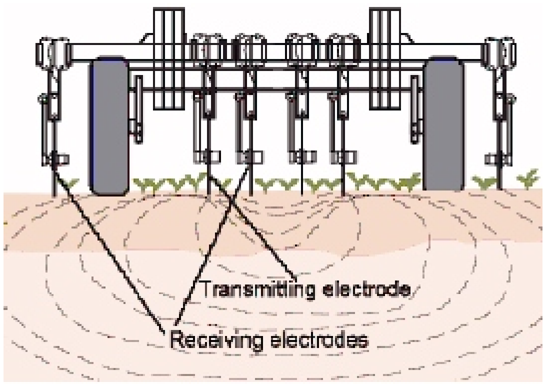

Fig. 2: Principle of operation for the contact type EC sensor. Selected coulters act as transmitting electrodes and others as receiving electrodes. (Veris Technologies, 2004; Salina, Kansas)

Fig. 3: The apparatus fabricated by authors for measuring apparent soil electrical conductivity

pair provides electrical current into the soil (transmitting electrodes) while the other coulters (receiving electrodes) measure the voltage drop between them (Fig. 2). Soil EC information is recorded in a data logger along with location information. A Global Positioning System (GPS) provides the location information to the data logger. The contact sensor is most popular for precision farming applications because large areas can be mapped quickly and it is least susceptible to outside electrical interference. The disadvantage of this system is that it is bulkier than non-contact sensors, and cannot be used in small experimental plots and some small fields.

Currently, Veris Technology manufactures a contact type of EC measuring device. Several models of Veris units are available commercially. For example, one model provides EC readings from two different depths (1 foot and 3 feet). A smaller model can be pulled by a small ATV, but it only provides EC measurements at a single depth. Both models can be pulled behind a truck at field speeds up to 10 mph. The distance between measurements passes ranges from 20 to 60 feet, depending on the desired sampling density or the amount of soil variability within the field. Because the Veris product is so expensive, the authors fabricated a similar apparatus for measuring apparent soil electrical conductivity in Iran farms (Fig. 3). The apparatus is ready for using in farms. The fabrication's cost is much less than the foreign brand type cost.

Non-contact sensor measurements: Non-contact EC sensors work on the principle of electromagnetic induction (EMI). EMI does not contact the soil surface directly. The instrument is composed of a transmitter and a receiver coil (Fig. 4), usually installed at opposite ends of the unit. A sensor in the device measures the resulting electromagnetic field that the current induces. The strength of this secondary electromagnetic field is proportional to the soil EC. These devices, which directly

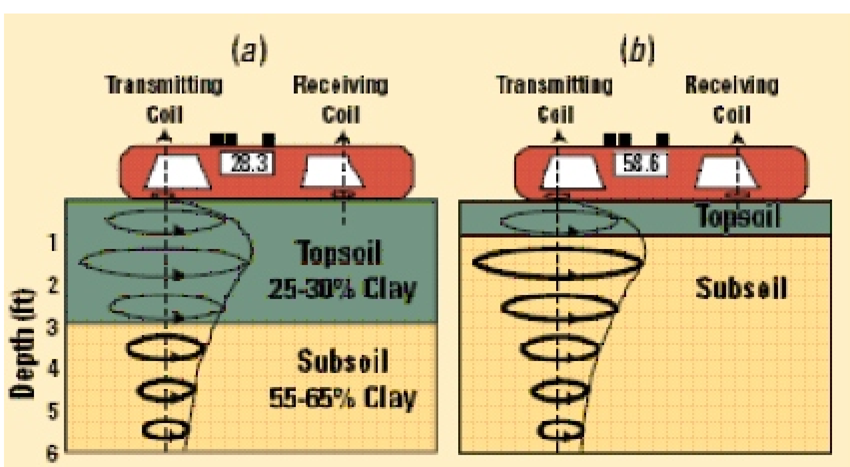

Fig. 4: Principle of operation for the non-contact type EC sensor (Davis *et al*., 1997)

measure the voltage drop between a source and a sensor electrode, must be mounted on a non-metallic cart to prevent interference. These sensors are lightweight and can be handled easily by a single individual, thus making them useful for small areas. EM38 (Geonics Limited, 2005) and GEM-2 (Geophex, 2005) are two popular models of non-contact sensors. GEM-2 is a digital, multi-frequency sensor that is capable of measuring EC at different depths. EM-38 works only with a fixed frequency and has an effective measurement depth of 5 feet in horizontal mode or 2.5 feet in vertical mode.

CONCLUSION

Iran is a populous and dry country, which needs to have a productive agriculture. Precision agriculture tends to be the only way for having a sustainable yield in farms. Performing precision agriculture needs knowledge about soil characteristics such as salinity, CEC and water content. Measurement of apparent soil electrical conductivity is one of the easiest ways to get suitable information about soil characteristics. Beside easiness, the low price of measuring apparent soil electrical conductivity introduces it as the best way for developing precision agriculture.

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