Asian Journal of Agricultural Sciences 2(4): 168-173, 2010
ISSN: 2041-3890

Submitted Date: May 19, 2010 Accepted Date: June 01, 2010 Published Date: October 09, 2010

Design and Development of a Portable Soil Electrical Conductivity Detector

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Abstract: Design and development of a soil electrical conductivity measuring unit is the aim of this study. 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 climate variation in different regions. For these reasons, agriculture in Iran must be able to produce food not only for Iranian people but also for the other people of the world enabling native farmers to compete with foreign farmers. For having a sustainable agriculture it is needed to know the soil characteristics, shortages and abilities. Soil electrical conductivity was used for field scale application for measuring soil salinity, cation exchange capacity, soil water content and soil temperature. A portable soil Electrical Conductivity (EC) detector was designed and developed. The EC detector adopts a four-electrode method and consists of these parts: four disks as electrodes, a power source, a function generator and the data acquisition unit. Two electrodes inject a constant electrical current into the soil and the voltage drop detects between two other electrodes. The power and recorder units consist of several sections including the power source, the function generator, the A/D conversion section, the display section, and the data acquisition section. The detector is useful for field scale survey and does so fast soil electrical conductivity measurements of the field.

Key words: Climate, detector, Iran, precision agriculture, salinity, soil electrical conductivity

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. 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). Iran inappropriate soil and climatic conditions made a lot of problems for farmers.

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 country-wide 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. 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

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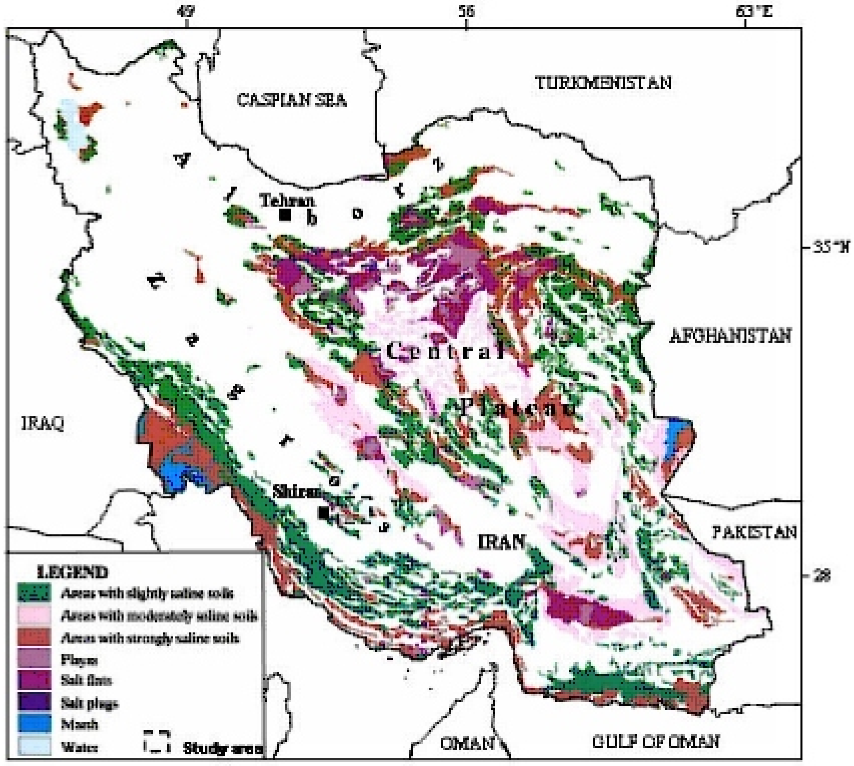

Fig. 1: Distribution of salt-affected soils in Iran (from SWRI 2000, changed)

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).

Distribution of different climatic conditions in Iran: In Table 1 (Anonymous, 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 for agriculture.

From Table 2 (Anonymous 2007), it can be seen that the major climatic condition 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. Apparent soil electrical conductivity is one of the simplest, least expensive soil measurements to obtain useful information about soil characteristics, which have a vital role in precision agriculture. Soil EC measurement can provide more information in a shorter amount of time than traditional grid soil sampling (Grisso *et al.*, 2007).

Doerge *et al.* (1999) reported that pore continuity, water content, salinity level, cation exchange capacity, soil depth and temperature are the main factors effecting soil electrical conductivity. Therefore, measuring soil electrical conductivity enables farmers to find the relationship between soil EC and other important soil factors. Soil solution electrical conductivity (EC_s) and bulk soil electrical conductivity (EC_b) are two parameters describing soil electrical conductivity. By preparing a soil solution and measuring the EC, EC_s is obtained and assumed to be representative of the bulk soil EC (Zuo *et al.*, 2001). This kind of measurement has a high accuracy and is considered to be the standard method for soil EC measurement. Since this process is complex and time consuming, it is useless for real-time and large-scale

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

Number	Climate	Ultra-Arid	Arid	Semi-arid	Mediterranean	Semi-Humid	Humid	Ultra-Humid
	Province	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	Markazi	0	31.59	59.99	8.13	0.22	3.06	0
2	Gilan	0	2.64	3.71	2.15	9.47	17.4	53.12
3	Mazandaran	0	0	1.41	3.28	16.83	27.77	43.31
4	Golestan	0	18.94	43.55	8.8	7.52	12.29	8.88
5	Ardebil	0	0.15	51.92	20.14	11.64	12.1	4.06
6	Northern Azerbayejan	0	1.48	52.66	18.72	16.56	7.85	2.74
7	Southern Azerbayejan	0	0.68	46.59	16.82	9.14	16.43	10.36
8	Kermanshah	0	5.45	36.27	17.66	12.37	22.5	5.76
9	khoozestan	17.56	48.03	19.22	4.64	4.02	4.82	1.68
10	Fars	4.31	43.32	38.77	6.63	2.85	2.67	0.23
11	Kerman	56.48	33.78	6.72	2.03	0.39	0.04	0
12	Khorasan	35.59	39.7	21.45	2.12	0.61	0.45	0.08
13	Esfahan	61.15	21.78	7.92	2.98	1.46	0.81	2.29
14	Hormozgan	33.64	65.76	0.46	0.15	0	0	0
15	Sistan baloochestan	73.76	25.7	0.07	0	0	0	0
16	Kordestan	0	0	23.7	27.1	20.22	25.55	3.42
17	Hamedan	0	0	73.47	16.18	4.71	3.8	1.21
18	Lorestan	0	0	35.79	18.29	12.39	15.14	18.39
19	Ilam	0	40.21	43.38	11.68	4.73	0	0
20	Zanjan	0	1.69	70.33	19.32	5.81	2.58	0.27
21	Ghazvin	0	20.07	53.14	14.57	8.27	2.44	1.51
22	Charmahalobakhtiri	0	0.74	16.85	13.56	14.06	14.69	40.11
23	Kohkilooye va Boyerahmad	0	0.25	27.01	15.76	30.02	19.11	7.86
24	Semnan	59.86	28.63	6.04	1.6	1.88	1.11	0.82
25	Yazd	83.9	13.50	2.51	0	0	0	0
26	Booshehr	3.02	82.26	14.69	0	0	0	0
27	Ghome	38.93	51.02	5.82	0.01	0	0	0
28	Tehran	0	33.17	20.11	6.4	6.91	12.68	19.99

survey needed for precision agriculture (Li *et al*., 2006). Bulk soil electrical conductivity EC_b has been extended to soil characterization in agriculture. Noncontact and contact are two methods for measuring EC_b (Corwin and Lesch, 2003). Figure 2 shows the principle of the non-contact type of EC_b sensor. It is based on the theory of Electromagnetic Induction (EMI). Two coils namely transmitter and a receiver are placed about 1 m apart in a non-conductive casing. An alternating current applied to a copper coil induces an electromagnetic wave in the transmitter, known as the primary magnetic field, which their loops are shown in the Fig. 2. After contacting magnetic field with the conductive material in soil, an eddy current in the soil matrix is created. This eddy current generates a secondary magnetic field. Since the measured response is a function of soil EC, it can be evaluated by this kind of sensor (Robinson *et al*., 2003).

Contact sensor is based on the four-electrode method. Constant electric current is injected from the power source into the soil with transmitting electrodes and the voltage is measured with a voltage meter connected to receiving electrodes (Fig. 3). Using the voltage drop, the soil EC_b can be measured (Bartnikas, 1987; Telford *et al*., 1976; Sun and Wang, 2001).

Because of easiness and less susceptibility to outside interference of the contact method, it has a better chance to cover a big area (Ehsani and Sullivan, 2002). The main objective of the study is to design and develop a soil EC measurement instrument, which can make on the go measurements of apparent soil electrical conductivity in farms. The goal was to design a device with high precision, and the least possible developing price. Using of this device should be easy and fast for farmers to measure soil electrical conductivity in farms.

Table 2. Summary of Iran climatic condition

Climates	Percentage Area	considerations
Ultra Arid	30.4	The major climate in 5 provinces
Arid	29	The major climate in 7 provinces
Semi Arid	19	The major climate in 11 provinces
Mediterranean	5	The major climate in 2 provinces
Semi Humid	5/3	________________
Humid	6/3	________________
Ultra Humid	5	The major climate in 3 provinces

MATERIALS AND METHODS

Design of the structure: Because the contact method was thought to be better suited to cover large areas with ease and to be less susceptible to outside interference (Ehsani and Sullivan, 2002), a contact type sensor was chosen to develop. Figure 4 shows the structure of the designed detector. Four stainless disks were adopted as electrodes. The frame was made from two hollow metallic bars with a rectangular cross-section that were connected with two perpendicular metallic channels. The power source and data recorder were placed between two frame bars. The detector won't collect reliable data unless there is an ideal

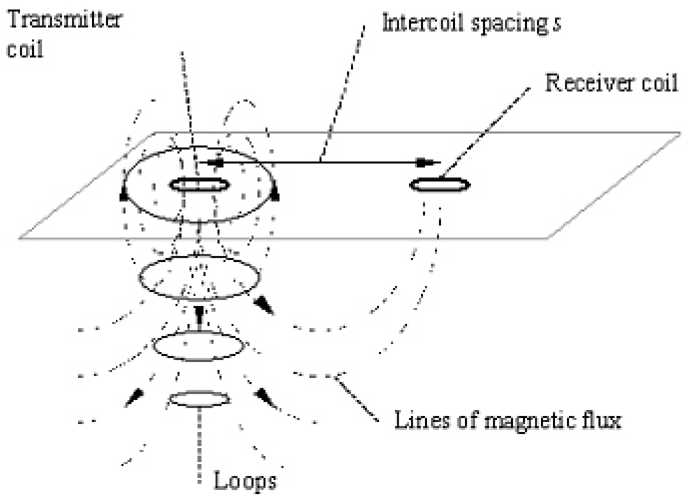

Fig. 2: Principle of noncontact soil EC_b sensor

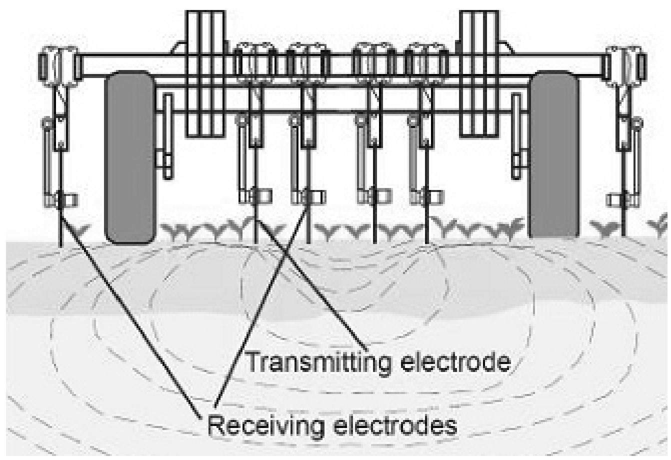

Fig. 3: Principle of contact soil EC_b sensor

Fig. 4: Structure of developed contact soil EC_b sensor

Fig. 5: The penetration of disk electrode into the soil

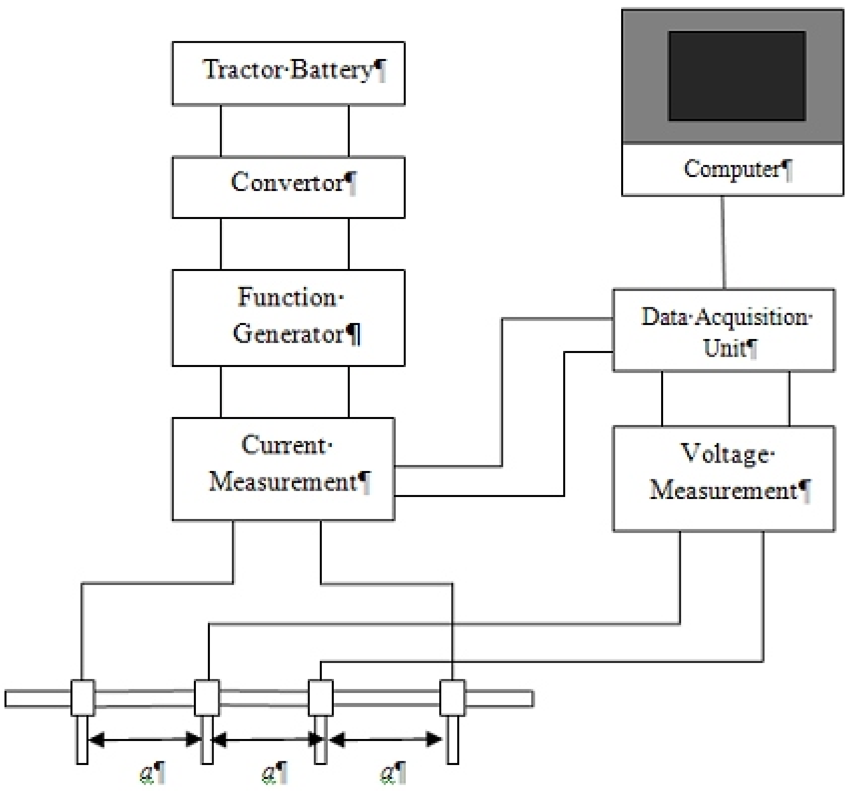

Fig. 6: The system block diagram of power source and signal recorder units

contact between the disks and soil. Therefore, the disks must penetrate 5-6 cm into the soil and it must be so loose to permit the electrodes penetrate into the soil (Fig. 5).

The power source and signal recorder units: The main functions of the power source and signal recorder units are: i) providing a constant current source to outside electrodes; ii) measuring the voltage drop between inside electrodes and executing A/D conversion; iii) changing the voltage drop into soil EC and displaying it; and iv) recording the EC data together with positioning data (GPS data) if necessary. Figure 6 shows the system block diagram of the units. It consists of several sections: the power source, the convertor, the function generator, the display, and the signal recorder sections. Estimating soil EC with the four-electrode method is on the basis of injecting constant current into soil. Thus it was clear that the source of the constant current was a very important section to the soil EC detector. Furthermore, since the detector would be used in fields, the power source should provide enough energy for the detector to work continuously for a long time. For this reason a convertor is designed for converting the 12V dc current of tractor's battery to 220V ac. The convertor's output is given to the function generator to produce 5V ac. The signals then are injected to soil among transmitting electrodes and the secondary signals are received with data acquisition unit. In the data acquisition unit analog signals are converted to digital signals, shown and recorded. After finishing field survey, the data are transferred to PC. With Excel software and using following formula the measured voltage was converted to soil EC. The depth of measuring soil electrical conductivity is equal to one third of the outer electrodes' distance. For example if "a" is the vicinal electrodes' distance then the depth of EC measurement is equal to "a" (Fig. 6).

$$EC = \frac{1}{2\pi aV} \tag{1}$$

In this formula $'I'$ is the injected current value, $'V'$ is the measured peak voltage value and $'a'$ is the vicinal electrode distance in meter. The common unit of electrical conductivity is milliSiemens per meter (mS/m1) but it can be reported in units of deciSiemens per meter (dS/m), which is equal to the reading in mS/m divided by 100.

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. A detector, which can do on the go soil electrical conductivity measurements, will have a vital role for developing agriculture in Iran.

REFERENCES

Anonymous, 2007. Retrieved from: http://soils.blogfa.com/cat-7.aspx.

Bartnikas, R., 1987. Engineering Dielectrics: Electrical Properties of Solid Insulating Materials Measurement Techniques. ASTM Special Technical Publication, Philadelphia, Pa, pp: 221-234, 926. ISBN: 0-8031-0491-X.

Corwin, D.L. and S.M. Lesch, 2003. Application of soil electrical conductivity to precision agriculture - theory, principles, and guidelines. Agron. J., 95(3): 455-471.

Dewan, M.L. and J. Famouri, 1964. The Soils of Iran. FAO, Rome, pp: 319.

Doerge, T., N.R. Kitchen and E.D. Lund, 1999. Soil Electrical Conductivity Mapping. Site Specific Management Guidelines, Potash and Phosphate Institute Publication, SSMG-30.

Ehsani, R. and M. Sullivan, 2002. Soil electrical conductivity (EC) sensors, Ohio State University Fact Sheet (AEX-565-02), Columbus, Ohio.

FAO, 2000. Global Network on Integrated Soil Management for Sustainable Use of Salt-Affected Soils. Retrieved from: http://www.fao.org/ag/agl/agll/spush/topic2.htm#iran

FAO, 2005. AQUASTAT, Country Profile Iran. Retrieved from: http://www.fao.org/ag/agl/aglw/aquastat/ main/ index.stm.

Ghassemi, F., A.J. Jakeman and H.A. Nix, 1995. Salinisation of Land and Water Resources. CAB International, Wallingforth, pp: 562.

Grisso, R.B., M. Alley, D. Holshouser and W. Thomason, 2007. Precision Farming Tools: Soil Electrical Conductivity. Virginia Cooperative Extension. Publication, pp: 442-508.

Kehl, M., 2006. Saline Soils of Iran with Examples from the Alluvial Plain of Korbal, Zagros Mountains Soil and Desertification - Integrated Research for the Sustainable Management of Soils in Drylands. 5-6 May, 2006. Hamburg, Germany, Retrieved from: www.desertnet.de/proceedings/start.html.

Li, M., M. Wang and Q. Wang, 2006. Development and performance test of a portable soil EC detector. Appl. Eng. Agr., 22(2): 301-307.

Robinson, D., S. Lesch, I. Lebron and P. Shouse, 2003. Minimizing drift in electrical conductivity measurements in high temperature environments using EM-38. Soil Sci. Soc. Am. J., 68(2): 339-345.

Siadat, H., 1998. Iranian agriculture and salinity. Proceeding of the Conference on New Technologies to Combat Desertification, 12-15 October 1998, Tehran, pp: 10-14.

Sun, Y. and M. Wang, 2001. A mathematical model and its experimental study for a kind of measurement method of soil electric conductivity. T. Chinese Soc. Agr. Eng., 17(2): 20-23.

SWRI (Soil and Water Research Institute Iran), 2000. Soil Resources and use Potentiality Map of Iran (1:1 000 000), Tehran.

Telford, W.M., L. Geldart and R. Sheriff, 1976. Applied Geophysics. Cambridge University Press, Cambridge, UK, pp: 633-640.

Zuo, Y., Y. Wei, H. Wang and J. Li, 2001. On the design and research of an intelligent conductivity gauge. T. Chinese Soc. Agr. Eng., 17(2): 161-164.