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Influence of salinity on soil chemical properties and surrounding vegetation of Awe salt mining site, Nasarawa State, Nigeria

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This study was carried out to monitor and document the influence of salinity on soil chemical properties and surrounding vegetation of Awe salt mining site, Nasarawa State, Nigeria. The soil samples were collected randomly from the salt mining site and 10 m away from the site (control) at 5, 10, 15 and 20 cm depths, respectively, with three replications each. The soil samples were air dried, sieved and the physical and chemical properties were determined using standard methods. The exchangeable sodium percentage (ESP), cation exchange capacity (CEC) and sodium adsorption ratio (SAR) were calculated. No plant was found growing on the salt mining site (SMS) unlike the control site (CTS) which has a little diversity of plants. The soil organic carbon, organic magnesium, total nitrogen and phosphorus at SMS decreased significantly (α = 0.05) with soil depth in relation to CTS except for 10-15 cm soil depth. Soil exchangeable acidity (H^+ and Al^{3+}) at SMS significantly increased (α = 0.05) when compared with the CTS at different soil depths. Also, K^+, Na^+ and Mg^{2+} of SMS and CTS significantly increased (α = 0.05) at the different soil depths. Soil pH, electrical conductivity (EC), ESP and SAR at SMS significantly increased at different depths when compared with CTS. Awe salt mining has brought about soil nutrient imbalance at CTS with EC less than 0.2 dS/m and SAR between 0-3. Thus, it is concluded that soil at CT and SMS is a sodic soil which have reduced the diversity of plants species.

Key words: Cations exchange, mining, salinity, sodicity, Awe town.

INTRODUCTION

Soil is the world's largest terrestrial carbon (C) sink, and is estimated to contain approximately 1600 Pg of C to a depth of one metre (Eswaran et al., 1993). Salt-affected soils, as they are called, are either saline or sodic. Saline soils refer to soils with electrical conductivity above 4 dS/m and usually contain sufficient soluble salts that adversely affect the growth of most crops (Allotey et al., 2008). The soluble salts are mainly chlorides and sulphates of sodium, calcium and magnesium. Sodic soils refer to soils with exchangeable sodium percentage above 15, with sodium salts capable of alkaline hydrolysis and are mainly Na_2CO_3 (Allotey et al., 2008). These two main groups of salt-affected soils differ (physically, chemically, biologically, as well as their geographical and geochemical distribution) and therefore, require different approaches for their reclamation and agricultural utilization. Salinity in soil or water is one of the major stresses and can severely limit crop production

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(Ashraf and Harris, 2004).

Salts have been a known problem for thousands of years, particularly in arid and semiarid areas where there is insufficient rainfall to leach salts from the root zone (Miller and Donahue, 1995). This problem usually arises when the total amount of salts which accumulate in the root zone is high enough to negatively affect plant growth. Excess soluble salts in the root zone restrict plant roots from withdrawing water from the surrounding soil, effectively reducing the plant available water (Bauder and Brock, 2001; USDA, Natural Resources Conservation Service, 2002). Under irrigated agriculture, salts are added continuously to the soils with each irrigation event (Qadir et al., 2005). Thus, soil salinity is a major threat to the sustainability of irrigated agriculture (Ghassemi et al., 1995). Approximately 932 million ha of land worldwide are degraded due to salinity and sodicity, usually coinciding with land available for agriculture. Of this area, salinity affects 23% of arable land while saline-sodic soils affect a further 10% (Szabolcs, 1989).

Soil water salinity can affect soil physical properties by causing fine particles to bind together into aggregates. This process is known as flocculation and is beneficial in terms of soil aeration, root penetration and root growth (Neumann, 1995). Saline soils contain sufficient soluble salts to suppress plant growth through a series of interacting factors such as osmotic potential effect, ion toxicity and antagonism, which induce nutrient imbalances (Neumann, 1995). Salinity imposes serious environmental problems that affect grassland cover and the availability of animal feed in arid and semi-arid regions (El-kharbotly et al., 2003). Salt stress undesirably affects plant growth and productivity during all developmental stages. Aslam (2006) pointed out that tree planting is the cheapest and most simple natural biological approach to controlling salinity.

Therefore, changes in salinity and sodicity affect soil physical and chemical properties, which subsequently alter nutrient cycles and decomposition processes (Wong et al. 2005). The risk of erosion is increased, while soil physical and chemical properties are altered, impacting upon aggregation and nutrient cycling as well as biotic activity. Therefore, there is a clear linkage between land management practices through their effect on salinity and sodicity (Wong et al., 2005). An excess of sodium on the cation exchange sites of fine-textured soils forms a condition in which irrigation water entering the soil is attracted to small pores with a great amount of force, resulting in soil swelling, particle slaking from aggregates, and dispersion, thus precluding drainage (Dollhopf, 2000). Upon drying, dispersed soil particles undergo a reorientation, resulting in lost of soil structure, lower hydraulic conductivity, and surface crusting that can break plant stems, inhibit germination and emergence, and slow infiltration (Dollhopf, 2000).

Soils affected by salinity, that is, those soils high in soluble salts, are characterised by rising water tables and waterlogging of lower lying areas in the landscape. Sodic soils are high in exchangeable sodium, slake and disperse upon wetting (Nelson et al., 1996). In addition, a few studies are available that unambiguously demonstrate the effect of increasing salinity and sodicity on soil C dynamics (Nelson et al., 1997; Pankhurst et al., 2001; Sarig et al., 1993). Generally, responses to salinization have been of two general kinds; engineering the environment to manage increased salt in the soil by irrigation and drainage management, or by “engineering” the plants to increase their salt tolerance. Salt tolerant plants may also ameliorate the environment by lowering the water table in salt affected soils (Pitman and Lauchli, 2002).

Nasarawa State, Nigeria is a state known for different types of solid minerals. Awe is a local government area in Nasarawa State, Nigeria where salt is been processed locally from soil and water from the river. It has an area of 2,557 km^2 and a population of 112,574 in the 2006 census. Despite the large area cover by salt, data on the magnitude of changes in soil chemical properties as affected by salinity remains sparse. Hence this research was conducted to monitor and documents the status of soil chemical properties of Awe salt mining site, Nasarawa State and its influence on surrounding vegetation.

MATERIALS AND METHODS

Study location

Awe town in Nasarawa state, Nigeria is located between longitudes 9°08'09, 50" E and latitudes 8°09'29, 06" N. Generally, fishing and farming are the main occupations of the people in the area. Maize, pepper and cassava are the main crops cultivated.

Plant collection and identification

Two sample plots of sizes 10 x 10 m were used for this survey in both salt mining site (SMS) and control site (CTS). The CTS was chosen to be 10 m away from the salt mining site. All the plants species at the two sites were collected, pressed, dried and identified using the herbarium of Department of Botany, Obafemi Awolowo University, Ile-Ife, Nigeria.

Soil collection and preparation

The soil in this area was mainly sandy loamy. Soil was collected randomly from the SMS at different depths using a soil auger (5, 10, 15 and 20 cm) during the rainy season. Also, soil was collected from CTS (10 m away from the SMS) at the same four different depths so as to know the changes in the chemical compositions. These collections were replicated thrice. The soil was air-dried and sieved using 2 mm mesh gauze to remove debris.

Laboratory analysis

The pH of the soil was determined in 2:1 $CaCl_2$/soil suspension using glass electrode pH meter (Crockford and Norwell, 1956). Electrical conductivity (EC) was determined using the method of

Rayment and Higgison (1992). Organic carbon (OC) and organic matter (OM) were determined by the Walkley and Black (1934) dichromate oxidation method.

Total nitrogen (N) was determined by the Kjedhal method (Jackson, 1958). Available phosphorus (P) was extracted by 0.03M NH_4F + 0.025M HCl (Bray and Kurtz, 1945) and the P in the extract were determined by colorimeter. Potassium (K) and sodium (Na), calcium (Ca) and magnesium (Mg) were extracted by 1.0 M ammonium acetate using leaching method. Micro nutrients (iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn)) were extracted with Hec and determined by buck scientific atomic absorption spectrophotometer (210/211vgp).

Calculations

The exchangeable sodium percentage (ESP) of the soil was calculated using Mohsen et al. (2009) formula as follows:

$$ESP = \frac{\text{Exchangeable sodium}}{\text{Soil CEC}} \times 100$$

Where: Exchangeable acidity (EA) = H^+ + Al^{3+}, exchangeable cations (CEC) = Na + Ca + K + Mg

$$\text{SAR (sodium adsorption ratio)} = \frac{[Na]^+}{½\{[Ca] + [Mg]\}}$$

RESULTS

No plant was found growing on the SMS. However, at the CTS, there was a little diversity of plants growing. The plants and their percentage proportions are highlighted in Table 1. Two families of plant that dominated the control site are Malvaceae and Tiliaceae each having a percentage population of 28.6% out of the total population. *Azadiractha indica* is the species with the highest percentage proportion of 20% while *Senna occidentalis* is the species with the lowest percentage proportion of 8.3% as shown in Table 1 and Figure 1.

The results in Table 2 highlighted the impact of salt on soil OC, OM, total N and P. At CTS, soil OC, OM and total N ranges from 10-15cm < 15-20cm < 0-5cm < 5-10cm. Whereas at SMS, OC, OM and Total N ranges from 10-15cm > 0-5cm > 5-10cm > 15-20cm. Soil OC, OM, total N and P at SMS decreased significantly (α = 0.05) with soil depth in relation to CTS except for SMS at 10-15 cm soil depth.

Table 3 shows the effects of salinity on the exchangeable cations. At SMS, soil CEC and $Cacl_2$ had the highest value at 0-5 cm soil depth. Soil exchangeable acidity (H^+ and Al^{3+}) at SMS significantly increased (α = 0.05) when compared with the CTS at different soil depths. Also, CEC of CTS significantly increased (α = 0.05) at different soil depths.

Soil pH, EC, ESP and SAR at SMS significantly increased at different depths when compared with CTS (Table 4). The pH of the soil collected at CTS ranges from 7.4 - 8.5 at soil depth 0-5 to 15-20 cm which is slightly different from pH (8.6-8.9) of soil at SMS. At CTS, soil EC, ESP and SAR ranged from 0.0033±0.001, 2.33±1.28 and 0.308±0.239, respectively. Soil EC and SAR ranged from 0.048±0.039, 6.17±2.25 and 0.88±0.71, respectively at SMS.

DISCUSSION

The zero plant diversity at the SMS might have been a long term effect of the saline conditions of the soil which had inhibited the ability of plants to take up water and nutrients. Plants uptake water through a process of osmo-regulation. When the soil solution salinity is greater than the internal salinity of the plant, water uptake is restricted. Thus, it brings about reduction in plant growth and biomass. This work agrees with that of Munns (2002) that salt stress decreases growth in most plants, including halophytes. Also, Abari et al. (2011) observed that NaCl and KCl salt stress decreased germination percentage and speed in *Acacia oerfota* and *Acacia tortilis*. Jamil et al. (2005) stated that increasing salt concentration decreases the germination percentage and rate at an important degree and increases germination time. In another study, the effect of sea water salinity (1500, 2500 and 3500 ppm) on the growth of tomato (*Lycopersicon esculentum*) cultivars revealed that the sea water salinity delayed seed germination and reduced germination percentage especially with increasing salinity level (Hajer et al., 2006).

Therefore, it is possible over time that the plant diversities at the CTS may also be lost gradually as the soil is also being affected by salinity. This is because out of the seven plant species identified at the CTS, only three species have been found to have tolerance to salinity. *Calotropis procera* is a salt tolerant plant to a relatively high degree and is native to Nigeria. It is usually an indicator of over-cultivated or exhausted soils and prefers disturbed sandy soils (Orwa et al., 2009). This is a further indicator of the soil nutrient status of CTS. *Corchorus aestuans* and *Triumfetta rhomboidea* of the same family Tiliaceae have also been reported to have high degree of tolerance to salinity (Islam et al., 2013).

In saline soils, the soil organic carbon content is influenced by two opposing factors: reduced plant inputs and reduced rates of decomposition. This might have been responsible for the significant decrease in the soil OC, OM, Total N and P observed in this work at SMS as the soil depth increases. This trend was in reverse order at the CTS. Therefore, soil salinity decreases plant productivity and hence carbon inputs to the soil at SMS (Coleman et al., 1997).

The salinity had slightly increased the soil Na^+, K^+, Mg^{2+}, Ca^{2+} and $CaCl_2$ at CTS. This is possibly an accumulated effect over time. Low value of CEC observed at 10-15 cm soil depth at SMS could be as a result of high

Table 1. Percentage proportion and degree of salt tolerance of plants identified at control site (CTS) of Awe salt mining area of Nasarawa State, Nigeria.

Scientific name of plant	Family	Degree of salt tolerance	Proportion (%)
Azadiractha indica	Meliaceae	Zero	20.0
Calotropis procera	Asclepiadaceae	High	14.5
Corchorus aestuans	Tiliaceae	High	11.5
Senna occidentalis	Caesalpiniaceae	Zero	8.3
Sida acuta	Malvaceae	Zero	15.0
Sida corymbosa	Malvaceae	Zero	13.6
Triumfetta rhomboidea	Tiliaceae	High	17.1

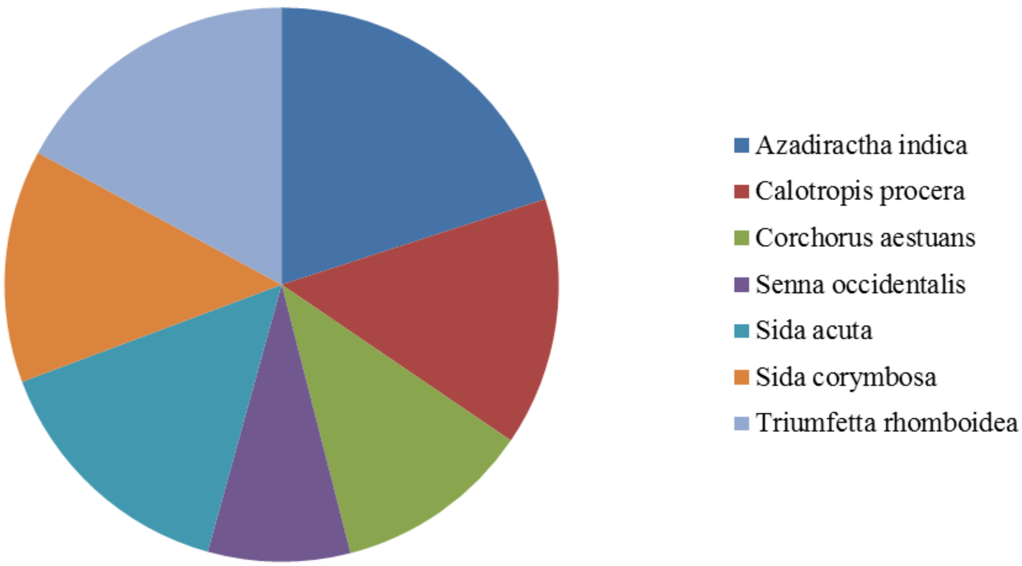

Figure 1. A chart showing the percentage proportions of the plants identified at control site of Awe salt mining area, Nasarawa State, Nigeria.

Table 2. Effect of salinity on OC, OM, total Na and P.

Depth (cm)	Location	OC (%)	OM (%)	Total N (%)	P (Ppm)
0-5	CT	1.17[c]	2.01[c]	0.1031[c]	0.000382[a]
5-10	CT	4.72[d]	8.12[d]	0.3530[d]	0.000449[d]
10-15	CT	0.20[a]	0.34[a]	0.0166[a]	0.000438[c]
15-20	CT	1.13[b]	1.95[b]	0.0929[b]	0.000404[b]
0-5	SMS	0.55[b]	0.94[b]	0.0495[b]	0.000511[c]
5-10	SMS	0.66[c]	1.14[c]	0.0556[c]	0.000404[a]
10-15	SMS	2.07[d]	3.56[d]	0.1695[d]	0.000404[a]
15-20	SMS	0.31[a]	0.54[a]	0.0265[a]	0.000410[b]
LSD (0.05)		3.87	6.66	0.293	0.0001269

CT = 10 m away from the mining site and SMS = salt mining site.

concentration of OC, OM, total N and P. It is known that increasing organic matter would increase the CEC values and subsequently decreased the ESP values. This is similar to study of Hill and James (1995) who reported

Table 3. Effects of salinity on exchangeable cations.

Depth (cm)	Location	EA (cmol/kg)	H^+ (cmol/kg)	Al^{3+} (cmol/kg)	K^+ (cmol/kg)	Na^+ (cmol/kg)	Mg^{2+} (cmol/kg)	Ca^{2+} (cmol/kg)	$Cacl_2$ (cmol/kg)
0-5	CT	1.4^b	0.20^a	1.20^c	0.42^c	0.44^d	2.53^c	7.00^a	7.10^a
5-10	CT	1.3^a	0.80^c	0.40^a	0.50^b	0.25^c	1.84^b	10.40^d	7.60^b
10-15	CT	2.5^d	1.90^d	0.60^b	0.60^a	0.20^b	2.76^d	9.50^c	7.70^c
15-20	CT	1.9^c	0.50^b	1.40^d	0.30^b	0.17^a	1.38^a	8.40^b	7.70^c
0-5	SMS	1.3^a	0.70^a	0.50^a	1.11^c	1.65^c	3.91^d	11.0^d	8.30^d
5-10	SMS	2.3^b	0.90^b	1.40^c	0.81^b	0.61^d	2.99^b	10.80^c	8.20^b
10-15	SMS	3.2^d	2.00^c	1.20^b	0.58^a	0.40^a	3.22^c	4.60^b	8.10^a
15-20	SMS	2.6^c	0.90^b	1.70^d	0.58^a	0.49^b	1.84^a	4.30^a	8.20^c
LSD(0.05)		1.356	0.328	1.155	0.309	0.737	0.754	6.80	0.5719

CT = 10 m away from the mining site and SMS = salt mining site.

Table 4. Effects of salinity on conductivity of the soil.

Depth (cm)	Location	pH_{H2O}	EC (dS/m)	ESP	SAR
0-5	CT	8.0^a	0.005^c	4.36^d	0.647^d
5-10	CT	8.5^c	0.002^b	1.95^c	0.319^c
10-15	CT	8.2^b	0.005^c	1.34^a	0.024^a
15-20	CT	8.5^c	0.001^a	1.66^b	0.243^b
0-5	SMS	8.6^a	0.110^d	9.34^d	1.910^d
5-10	SMS	8.7^b	0.034^c	4.01^a	0.073^a
10-15	SMS	8.9^c	0.021^a	4.54^b	0.640^b
15-20	SMS	8.7^b	0.026^b	6.79^c	0.884^c
LSD(0.05)		0.762	0.065	2.35	0.987

CT = 10 m away from the mining site and SMS = salt mining site.

that the addition of an organic amendment to soil is likely to increase the soil CEC simply from the additive effect of the organic matter and the high CEC associated with organic matter depending on soil pH.

Salinity limits water uptake by plants by reducing the osmotic potential and thus the total soil water potential. Salinity may also cause specific ion toxicity or upset the nutritional balance. In addition, the salt composition of the soil water influences the composition of cations on the exchange. The salinity at SMS has affected the pH and the exchangeable cations of CTS at soil depth 0-5 and 5-10. High value of EC, ESP and SAR at 0-5 cm could be as a result of high soil CEC and $Cacl_2$. Also, the higher soil pH, EC, ESP and SAR observed at SMS than CTS in this study is another proof of the effect of salinity on this soil. Therefore, soil at CTS and SMS were severely affected by salinity as the EC of both sites were < 0.2 and SAR values range between 0-3. This is confirmed by Miller and Gardiner (2007) who reported that when SAR is 0-3 and EC is < 0.2, the soil is sodic.

Conclusively, due to all the outcomes from this study, the influence of salinity on the soil in Awe salt mining area of Nasarawa State, Nigeria is sodic. This has really affected the plant diversities in the mining site and the control site. It is hereby recommended that appropriate soil reclamation technique be employed early in bringing back the soil to the form that can be suitable for agricultural production, in as much as the control soil is already affected.

REFERENCES

Abari KA, Nasr, MH, Hojjati M, Bayat D (2011). Salt effects on seed germination and seedling emergence of two Acacia species. Afr. J. Plant Sci. 5(1):52-56.

Allotey DFK, Asiamah RD, Dedzoe CD, Nyamekye AL (2008). Physico-Chemical Properties of Three Salt-Affected Soils in the Lower Volta Basin and Management Strategies for their Sustainable Utilization. W. African J. Appl. Eco. 12:163-182.

Ashraf M, Harris PJC (2004). Potential biochemical indicators of salinity tolerance in plants. Plant Sci. 166:3-16.

Aslam Z (2006). *Saline Agriculture.* In: Pakistan Agriculture Management and Development. Quraishi MAA, Zia MA, Quraishi MS (Eds.), pp. 210-221. A-One Publishers, Lahore, Pakistan.

Bauder JW, Brock TA (2001). Irrigation water quality, soil amendment and crop effects on sodium leaching. Arid Land Res. and Man. 15:101-113.

Bray RH, Kurtz LT (1945). Determination of total, organic, and available forms of phosphorus in soils. Soil Sci. 59:39-45.

Coleman K, Jenkinson D, Crocker G, Grace P, Klir J, Körschens M (1997). Simulating trends in soil organic carbon in long-term experiments using RothC-26.3. Geoderma 81:29-44.

Crockford L, Nowell R (1956). Laboratory manual of Physical Chemistry. John Wiley and Sons, New York, Expts. 31-32, 58-59.

Darmody, and W.L. Daniels (Eds.). pp. 21-40. American S. Agro., Madison, Wisconsin.

Dollhopf DJ (2000). Sampling strategies for drastically disturbed lands. In "Reclamation of Drastically Disturbed Lands". R.I. Barnhisel, R.G.

El-kharbotly A, Maghloub O, Al-subhi A, Al-halhali A (2003). Indigenous grass species with potential for maintaining rangeland and livestock feeding in Oman. Agric. Ecosyst. Environ. 95:623-627.

Eswaran H, Van den berg E, Reich P (1993). Organic carbon in soils of the world. Soil Sci. Soc. Am. J. 57:192-194.

Ghassemi F, Jakeman AJ, Nix HA (1995). Salinisation of land and water resources: Human causes, extent, management and case studies. UNSW Press, Sydney, Australia, and CAB International, Wallingford, UK.

Hajer AS, Malibari AA, Al-Zahrani HS, Almaghrabi OA (2006). Responses of three tomato cultivars to sea water salinity: Effect of salinity on the seedling growth. African J. Biotech. 5(10):855-861.

Hill RL, James BR (1995). The influence of waste amendments on soil properties, soil amendments and environmental quality. CRC Press, Inc. 0-87371-859-3/95.

Islam MS, Azam MS, Sharmin S, Sajib AA, Alam MM, Reza MS, Ahmed R, Khan H (2013). Improved salt tolerance of jute plants expressing the *katE* gene from *Escherichia coli.* Turk. J. Biol. 37:206-211.

Jackson ML (1958). *Soil Chemical Analysis*. p. 216, Prentice-Hall, Inc. Englewood Cliffs, N.J.

Jamil M, Lee CC, Rehman SU, Lee DB, Ashraf M (2005). Salinity (NaCl) tolerance of Brassica species at germination and early seedling growth. *Electron.* J. Environ. Agric. Food Chem. 4:970-976.

Miller RW, Donahue RL (1995). Soils in our environment. 7th edition. p. 323, Prudence Hall, Englewood, Cliffs, NJ.

Miller RW, Gardiner DT (2007). Soils in our environment. 9th edition, Pp. 452, Prentice Hall-Inc., Upper. Sddle River, New Jersey 07458.

Mohsen S, Majid R, Borzoo GK (2009). Prediction of soil exchangeable sodium percentage based on soil sodium adsorption ratio. American-Eurasian J. Agric. Environ. Sci. 5 (1):01-04.

Munns R (2002). Comparative Physiology of salt and water stress. Plant Cell Environ. 25:239-250.

Nelson PN, Barzegar AR, Oades JM (1997). Sodicity and clay type: influence on decomposition of added organic matter. Soil Sci. Soc. Am. J. 61:1052-1057.

Nelson PN, Ladd JN, Oades JM (1996). Decomposition of 14C-labelled plant material in a salt affected soil. Soil Biol. Biochem. 28:433-441.

Neumann PM (1995). Inhibition of root growth by salinity stress. In*:* Structure and Function of Roots. Baluska F, Ciamporova M, Gasporikova O, Barlow PW (Eds). pp. 299-304. Kluwer Academic Publishers, Netherlands.

Orwa C, Mutria A, Kindt R, Jamnadass R, Anthony S (2009). Agro-forestree Database: a tree reference and selection guide version 4.0. Available at http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp.

Pankhurst CE, Yu S, Hawke BG, Harch BD (2001). Capacity of fatty acid profiles and substrate utilization patterns to describe differences in soil microbial communities associated with increased salinity or alkalinity at three locations in South Australia. Biol. Fert. Soils 33:204-217.

Pitman MG, Lauchli A (2002). Salinity: Environment - Plants - Molecules. pp. 3-20. Kluwer Academic Publishers, Netherlands.

Qadir LM, Noble AD, Schubert S, Thomas RJ, Arslan A (2005). Sodicity-induced Land Degradation and its sustainable Management: problems and prospects. Land Degrad. Develop. DOI: 10.1002/ldr.751

Rayment GE, Higgison FR (1992). Australian Laboratory Handbook of Soil and Water Chemical Methods. Melbourne, Inkata Press (Australian Soil and Land Survey Handbooks vol. 3)

Sarig S, Roberson EB, Firestone MK (1993). Microbial activity-soil structure: response to saline water irrigation. Soil Biol. Biochem. 25:693-697.

Szabolcs I (1989) *Salt affected soils.* Pp. 274, Boca Raton, CRC Press.

USDA, Natural Resources Conservation Service (2002). Soil Conservationists. Salinity Management Guide - Salt Management. Available at http://www.launionsweb.org/salinity.htm.

Walkley A, Black IA (1934). An Examination of Degtajaroff method for Determining Soil Organic Acid Filtration Method*.* Soil Sci. 37:29-38.

Wong VNL, Greene RSB, Murphy BW, Dalal R, Mann S (2005). Decomposition of added organic material in salt-affected soils. IN ROACH, I. (Ed.) Cooperative Research Centre for Landscape Environments and Mineral Exploration Regional Regolith Symposia, 2nd-4th November. Canberra, CRC LEME.