SUDAN KNOWLEDGE

11 ASSESSMENT OF THE USE OF TREATED WASTEWATER FROM OIL REFINERY IN IRRIGATION, KHARTOUM-SUDAN

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ABSTRACT

PROBLEM: Sudan is currently facing a serious problem of disposal and reuse of waste water from different sources. In the oil industry, refinery waste water was estimated to be 20 million m^3/annum. Evaporation ponds were established in order to treat the waste water for further use, mainly irrigating trees as shelter belts and wind breaks around the refinery area.

OBJECTIVE: The ongoing tree planting efforts, using the refinery waste water for irrigation, seemed to be based on inadequate information regarding the use of the most suitable tree species in terms of both site adaptability and tolerance to the waste water quality. In addition, there were hazardous effects of waste water on the environment, mainly on soil characteristics.

METHODOLOGY: Six tree species (*Acacia tortili, Eucalyptus camadulensis, Azadrichta indica, Grewia tennax, Eugenia jambolana, and Conocarpus erectus*) were selected and used in a completely randomized block design in a field trial using refinery waste water for irrigation. Data were collected concerning plant growth parameters and performance throughout the experimentation period of 15 months. Soil samples were analysed after the application of waste water for quality assessment.

FINDINGS: The results of the experiment revealed a significant difference between all six tree species in their tolerance to waste water. These differences included number of leaves, number of branches, plant height and stem diameter. The most suitable tree species found were Conocarpus erecta and Acacia tortilis, while the least tolerant tree was Grewia tenax. Soil analysis results revealed a remarkable change in some soil characteristics after waste water application, mainly electric conductivity, pH and minerals concentrations.

VALUE: Refinery waste water could be used for irrigation purposes, but only under certain circumstances. Proper treatment measures should be introduced before the use of waste water. Soil quality was also important and certain precautions should be implemented before irrigation.

KEYWORDS: Reuse of wastewater, quality of refinery wastewater, soil quality

INTRODUCTION

The steady increase in the amount of water used and waste water produced by urban communities and industries throughout the world poses potential health and environmental problems. Countries are seeking safe, environmentally sound and cost-efficient ways to treat and dispose of waste water. At the same time, increased attention is being focused on the role that forestry, traditionally a rural-based sector, can play in improving the urban and sub-urban environment. One opportunity to combine these two concerns is the use of municipal waste water (both sewage and industrial effluent) to irrigate forests, forest plantations, greenbelts and amenity trees.

In Sudan the great amount of the daily discharge waste water from oil refineries needs proper management and recycling. The amount of waste is estimated to be about 20 million m3/annum. The idea was to get rid of the waste water by using an open pond evaporation system after preliminary pre-treatment. Despite the very high evapo-transpiration rate from the ponds, the amount of waste water is still substantial. Using this waste water discharge for the irrigation of some suitably selected tree crops is expected to play a dual purpose. It helps to dispose of the waste discharge water and simultaneously contribute to the environmental protection efforts through the establishment of trees in the form of shelterbelts or windbreaks or other forms of tree plantations.

The ongoing tree planting efforts, using the refinery waste water for irrigation, seemed to be based on inadequate information regarding the use of the most suitable tree species in terms of both site adaptability and tolerance to the type of waste water discharge from the refinery, and the trees' anticipated role in ameliorating the environment in the vicinity of the refinery. Hitherto, very few studies, if any, were carried out specifically for the use of discharge waste water from the Al Gaily refinery to irrigate tree crops. Recalling the successful green belt project in the southern suburbs of Khartoum in the early 1960s, the use of sewage plant water has a good reputation for success in Sudan. However, the chemical nature of the discharge waste water from the Gaily refinery has more serious environmental and health consequences on the area; therefore it calls for a different strategy and more innovative procedures.

Physiologically, trees can be considered as big and complicated chemical reactors. They can therefore be used to absorb many chemical wastes, although they differ enormously in their ability to absorb chemicals. Trees are normally planted on spoil soil collieries and similar sites to reclaim them. This suggests that some tree species are endowed with special physiological characteristics, such as salt or drought tolerance, which enables them to perform better than other types regarding adaptability to such harsh environmental conditions (KRC, 2014).

THE OBJECTIVES OF THE STUDY WERE:

1. To test the suitability of the use of the discharge for waste water irrigation of some selected tree crop species;
2. To identify the tree species that are most tolerant to waste water;
3. To monitor and assess the effect of the discharge waste water application on soil properties and its effect on a changing soil environment.

MATERIALS AND METHODS

Selected Tree Species in the Experiment

Indigenous tree species that were likely to be suitable for use in waste water disposal in the study area were limited; this is because of the poor tree cover due to the harsh dry environmental conditions. A limited number of trees, in addition to some well-known exotic tree species that were successfully tried locally on similar sites, will be trialled within this study (see Appendix 1).

FIELD TRIAL

- The selected tree species were planted in CRBD in the experimentation farm in the Al Gaily area. Waste water from the treatment ponds was used for irrigation (see Appendix 2). Plants were monitored for growth parameters (number of leaves, plant height, number of branches and stem diameter) during a growing period of 15 months;
- Soil samples were collected from the study site before (see Appendix 3) and after waste water application after 2 months (1st sampling), 7 months (2nd sampling) and 15 months (3rd sampling); they were then analysed for quality assessment.

RESULTS AND DISCUSSION

VARIATION IN HEIGHT GROWTH

Generally, the best performance in height growth was achieved by Canocarpus iructus, with a height of 80.93cm. It recorded the greatest length within 15 months, and was significantly different from all the other species used. On the other hand, Grewia tenax recorded the least height (5.57 cm) among the six species. Acacia tortilis ranked second in height performance, but was significantly shorter than Canocarpus iructus and significantly taller than the remaining tree species: it recorded an average height of 61.40cm. On the other hand, Eucalyptus camaldulensis and Eugenia jambolana ranked intermediate with no significant difference between them, but both of them showed significant differences from the other tree species: they recorded heights of 55.13cm and 46.02cm respectively. Azadirachta indica ranked second shortest, but was significantly different from all the other five tree species: it attained a height of 26.63cm.

NUMBER OF LEAVES

The number of leaves is an important variable that indirectly indicates the photosynthetic rate and food synthesis production efficiency in the whole plant. Generally trees differ substantially in the number of leaves they have depending on their genetic composition, leaf size, type and colour. Comparisons between trees regarding this characteristic might be misleading because it depends on several interrelated factors. Nevertheless, in this study we considered the relative number of leaves as a suitable criterion to differentiate between the different tree species used in the experiment.

In this connection, the biggest number of leaves was produced by Conocarpos irctus with 81 leaves, and a significantly larger number than the rest of the tree species. This tree species seems to be more tolerant to waste water than the remainder of the group through the retention of a larger number of leaves. Acacia tortilis ranked second in the number of leaves retained, although generally acacias are not reputed to be tolerant to waste water. It produced a significantly larger number of leaves compared with Eucalyptus camaldulensis that ranked third producing 40 leaves, and was also significantly different from the other four tree species. However, Grewia tenax showed a significantly lower number of leaves compared to the other five tree species examined. It seems that this species is so sensitive to waste water; most of its leaves were produced but defoliated immediately after their emergence. Means with the same letter in a column are not significantly different at ≥ 0.05 using the Duncan New Multiple Range Test

NUMBER OF BRANCHES

The largest number of branches was recorded by Conocarpos irctus with four branches, and Acacia tortilis with three branches during the 15-month period of early growth. Both tree species showed no significant differences between them in growth characteristics.

Grewia tenax and Azadirachta indica had the lowest number of branches during the 15-month growth period. This species was, however, ranked intermediate but significantly different from the five tree species. This variation in the number of branches between the tree species can be attributed to the variation in the variability of each species to waste water. However, trees are also genetically variable in their branching habit and degree of branching.

STEM DIAMETER

Diameter growth is an obvious indicator for sturdier growth of both root and shoot-systems. However, Conocarpos irctus produced a significantly larger diameter growth compared to the other five tree species. It recorded a diameter growth of 2cm, while the group of Grewia tenax, Eucalyptus camaldulensis and Eugenia jambolana ranked second with no significant differences between them and recording diameters of 1.33cm, 1.27cm and 1.27cm respectively.

Based on the results of the analysis of variance presented in Table 1, a mean separation procedure (the Duncan New Multiple Range Test) was employed to quantify and compare the variation between the six tree species used in the trial. There were highly significant differences between the six tree species used in the 15-month trial in height, diameter, number of leaves and number of branches characteristics.

Table 1: Variation in growth characteristics of six tree species grown in the field for 15 months using oil refinery wastewater

Species	Height (cm)	Number of leaves	Number of branches	Diameter (cm)
Conocarpos irctus	80.93a	81a	4. a	2.00a
Grewia tenax	5.57e		1d	1.331b
Eucalyptus camaldulensis	55.125 bc	40C	3bc	1.27b
Eugenia jambolana	46.029bc	40C	Dc	1.271b
Azadirachta indica	26.630 4c	14e	1d	0.53c
Acacia tortilis	61.397 ba	73b	3a	0.10d
Intention to visit a green hotel	0.00			

Source: Devised by authors

Table 2: ANOVA on growth characteristics of six tree species grown for 15 months in a field trial

Source	DF	Growth characteristics											
		Height			Diameter			Number of leaves			Number of branches		
		SS	MS	FV	SS	MS	FV	SS	MS	FV	SS	MS	FV
Period	4	6637.5	1659.4	6.50***	4.033	1.344	5.2**	25677	6419.3	16.13***	29.95	7.49	8.83***
Species	5	160836.6	32167.3	125.95***	41.54	8.308	32.12***	118563	23712.5	60.25***	44.19	8.84	10.42***

Source: Devised by authors

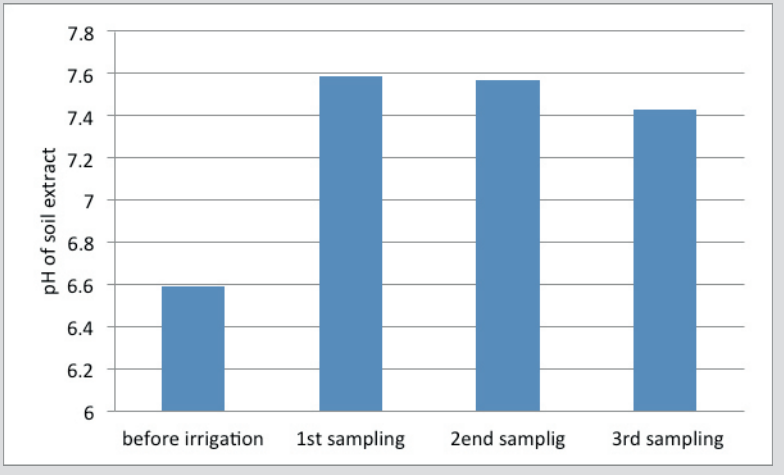
Table 2 depicts the variation between the above mentioned tree species with regard to the various variables examined. The following is a detailed description of these variations depicted with regard to the variables investigated.

EFFECT OF WASTEWATER APPLICATION ON SOME SOIL PROPERTIES

Soil pH:

A remarkable increase was observed in soil pH (Figure 1) after irrigation with refinery wastewater. This could be attributed to the availability of nitrate in wastewater.

Figure 1: pH variation of soil extract before and after application of wastewater

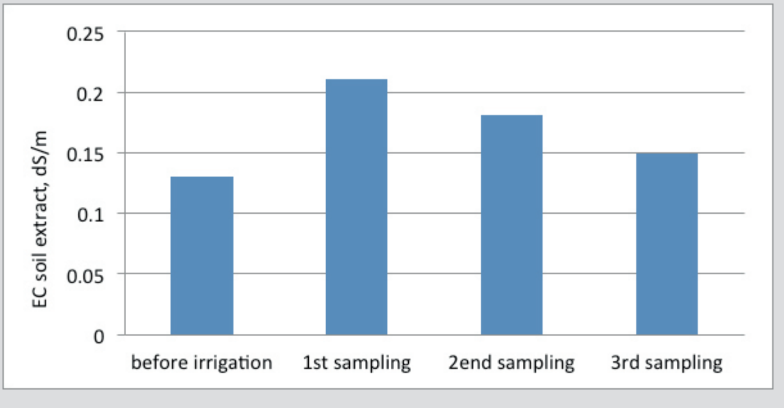


Source: Devised by authors

Soil Electric Conductivity (EC):

EC values (Figure 2) were also changed on wastewater application, which affected soil quality by increasing soil salinity levels.

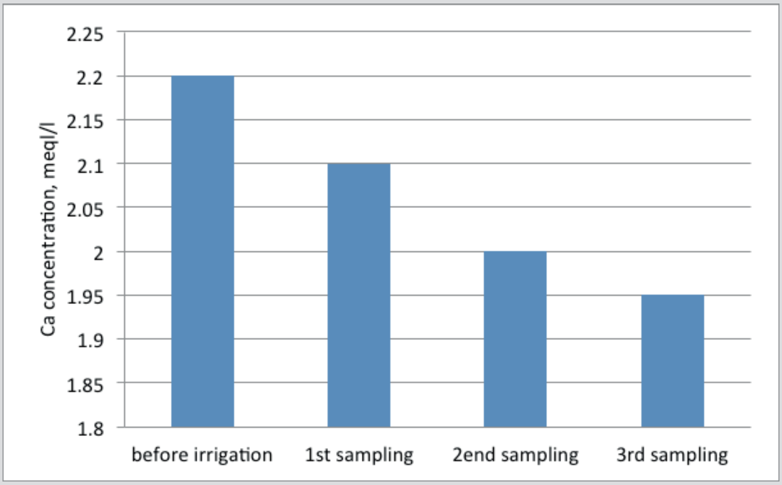
Figure 2: EC variation of soil extract before and after application of wastewater, dS/m



Source: Devised by authors

Calcium (Ca^{++}) concentration:
A significant decrease in Ca^{++} concentration (Figure 3) in soil extract was observed after the application of wastewater. This could be attributed to leaching of Ca^{++} downward after subsequent irrigation.

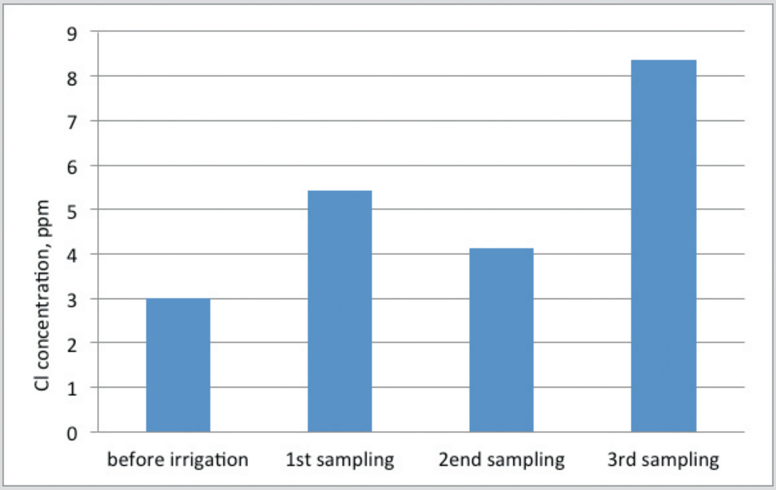
Figure 3: Calcium concentration of soil extract before and after application of wastewater, ppm



Source: Devised by authors

Chloride (Cl^-) concentration:
Chloride concentration in soil extracts (Figure 4) increases after irrigation with wastewater.

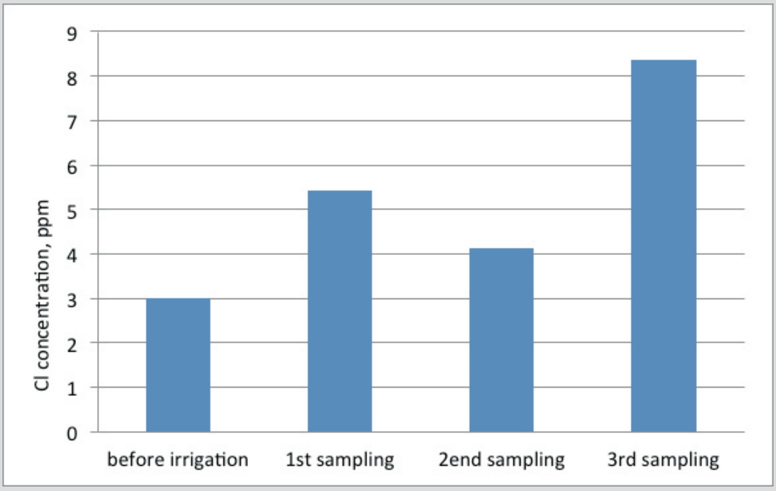
Figure 4: Chloride (Cl^-) concentration of soil extract before and after application of wastewater; ppm



Source: Devised by authors

Sodium (Na^+) concentration in soil extract:
A significant increase of Na+ concentration (Figure 5) was observed in the soil extract after wastewater application. This affected soil quality, and sodic condition will prevail.

Figure 5: Sodium (Na^+) concentration of soil extract before and after application of wastewater, ppm



Source: Devised by authors

CONCLUSIONS

The results of the experiment revealed a significant difference between all six tree species in their tolerance to wastewater with respect to number of leaves, number of branches, plant height and stem diameter.

The most suitable tree species found were Conocarpus erecta and Acacia tortilis, while the least tolerant tree was Grewia tenax.

Soil analysis results revealed a remarkable change in some soil characteristics after wastewater application mainly, electric conductivity, pH and minerals concentrations.

Refinery waste water could be used for irrigation purposes only under certain circumstances. Proper treatment measures should be introduced before wastewater use.

Soil quality was also important and certain precautions should be implemented before irrigation.

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APPENDICES

APPENDIX 1: DESCRIPTION OF TREE SPECIES

Tree	Description
Grewia tenax (Godiem)	Is an indigenous shrubby species, of low branching growth habit and multiple stems. Sometimes it is scrambling and up to 3m high. It is highly drought resistant and occurs in the driest savannas at desert margins and regions of higher rainfall, where it grows in thickets on termite mounds in otherwise seasonally flooded country. In the Sahel it grows in rocky places on hills and slopes, in regions with 100-600mm of rain per annum.
Acacia tortillis	Often called the 'umbrella thorn' for its distinctive spreading crown, it is one of the most widespread trees in seasonally dry areas of Africa and the Middle East. The umbrella thorn is the dominant tree in many savanna communities and provides an important source of browse for both wild and domesticated animals. Acacia tortilis occurs throughout dry Africa, ranging from Senegal to Somalia and down into South Africa. In Asia, trees occur in Israel, southern Arabia, and Iran. A. tortilis is found in all countries fringing the Sahara and is often the tree that extends furthest into the desert. Young A. tortilis forms natural thickets in heavily over-grazed savanna in southern Africa. The tree was introduced from Israel in 1958 into the district of Rajasthan, India, where it showed the greatest promise of 277 tested species. It is now widely planted in Rajasthan and has also been planted in Pakistan and on the Cape Verde Islands. Acacia tortilis occurs from sand dunes and rocky scarps to alluvial valley bottoms, avoiding seasonally waterlogged sites. A very drought resistant species, the umbrella thorn grows in areas with annual rainfall as low as 40mm and as much as 1,200mm, with dry seasons of 1-12 months. The tree favours alkaline soils but will colonize saline and gypseous soils. A. tortilis forms a deep tap root in sandy soils; the solitary landmark Tenere tree in the southern Sahara had roots reaching 35m deep. On shallower soils and in sand sites, it can develop hose-pipe subsurface roots extending over twice the width of the crown. The umbrella thorn ranges from 390->2,000m elevation. It survives sites where temperatures regularly reach 50°C at midday, and fall to near freezing at night. Older trees (>3m tall) can withstand frosts and light grass fires (Fagg, 1992).

APPENDIX 1: DESCRIPTION OF TREE SPECIES (CONTINUED)	
Tree	**Description**
Azadirachta indica A. Joss	Is widely known as Neem, a tree that has proven value to both city and farm dwellers throughout the dry tropics and subtropics. Neem has long been recognized as a versatile multipurpose tree for urban regreening, agro forestry, fuel wood production, and for a variety of other products, including biopesticides. Neem adapts to a broad range of climate and soil conditions. It is normally found at elevations between sea level and 700m. It can grow at altitudes up to 1,500m, as long as temperatures remain moderate, as it does not withstand cold or frost. Neem tolerates extremely high temperatures, but its normal range is about 9.5°C-37°C. It is also highly drought tolerant, and once established, it can survive 7-8 month dry seasons. It requires as little as 150mm rainfall per year in areas where the root system can access groundwater within 9-12m of the surface, however, it performs best in zones receiving 450-1,200mm/year. Neem prefers deep, permeable, sandy soils, but can be planted in a wide variety of soil types, including difficult sites where most other species do not perform well. It can thrive on rocky, dry, shallow, infertile soils, but is not recommended for silty or micaceous loams, silt clay soils, saline soils, or where sub-surface hardpan or laterite outcroppings occur (NRC, 1992). Neem should also not be planted on sites where soils become waterlogged or seasonally inundated. It prefers a soil pH in the 6.2-7.0 range, but can grow within a range of 5.0-8.0 pH. Mature neem trees are light demanders.
Ecualyptus camaldulen-sis (Ban)	A naturalized tree species to Sudan. Eucalyptus camaldulensis exhibits considerable morphological variation throughout its range, and consequently a number of intraspecific taxa have been described. It has been reported to be tolerant to a variety of harsh environment conditions. It has been successfully tried in the Khartoum green belt using sewage water for irrigation
Conocarpus erectus (damas)	Is a low branching; multi-trunked, shrubby, evergreen tree, and has glucose medium-green leaves.
Azadirachta indica A. Joss	Is a medium to large sized tree. It has a thick umbrella like crown, with dense foliage, casting heavy shade. Its distribution in Sudan is limited sparsely used as shade tree (Abdelnour, 2006).

Source: Devised by authors

APPENDIX 2: WASTEWATER CHARACTERISTICS

Samples	pH	EC dS/m	Oil mg/l	COD mg/l	Sulphide mg/l	Ammonia mg/l	Phenol mg/l	BOD mg/l
1	7.5	0.13	0.0	261	0.18	121.4	0.14	38
2	8.4	0.13	11.7	1355	0.18	104.8	30.8	36
3	7.4	0.12	13.1	164	0.07	69.8	0.11	36

Source: Devised by authors

APPENDIX 3: SOIL SAMPLES CHARACTERISTICS BEFORE IRRIGATION

Parameter	Results			
Depth (cm)		0-30	30-60	60-90
CaCO3 %		0	0	0
Particle size distribution %	CS	9	11	10
	FS	33	44	42
	Si	56	36	31
	Clay	12	9	17
Saturation %		32	31	34
Texture		L	L	LC
Exchangeable bases mmol/kg	Na^+	1.7	1.7	1.8
	K^+	0.18	0.18	0.19
CEC mmol/kg		35	38	40
N%		0.012	0.014	0.012
OC %		0.078	0.094	0.07
C/N		6.5	6.7	5.83
Available P mg/kg		1.4	1.6	2.2
pH paste		7	7.1	7.2
pH 1:5		7.5	7.4	7.2
EC (dS/m)		4.3	6.5	7.2
ESP %		8	14	15
Soluble Cations and Anions meq/l	Na^+	0.5	0.5	0.6
	Ca^{++}	1	1	1
	Mg^{++}	0.5	0.5	0.5
	Cl^+	0.9	1	1.2
	$CO3^{--}$	0	0	0
	$HCO3^-$	1.35	0.2	0.22

Source: Devised by authors

BIOGRAPHIES

Dr Sarra Ahmed Mohamed Saad was born in Sudan and awarded the PhD degree in Soil Science in 2002 from the University of Goettingen, Germany. She graduated from the Faculty of Agriculture, University of Khartoum majoring in Soil Science. She was appointed to the National Center for Research, Department of Environment in 1992, and is currently working as a senior researcher of Soil Science. She is leading many research projects dealing with the problem of food security, soil productivity and climate change, in addition to organic farming and its applications in Sudan. She is a member of many scientific societies inside and outside Sudan, and has been awarded prizes for scientific achievements in Sudan. She also holds some patents for producing compost from organic wastes. She has supervised many postgraduate students at both MSc and PhD level, and has offered consultancy to governmental and private sectors about organic food production and fertilization strategies, especially in poor fertile soils. In addition to Arabic, she speaks German, English, French and Spanish.

Dr Ahmed Mohmed Adam Eldoma, BSc Forestry Honors University of Khartoum, Faculty of Agriculture, MSc Natural Resources Management, Faculty of Science University of Edinburgh, Scotland, UK, and PhD Tree Physiology and Genetics UPM, Malaysia. Currently, Associate Professor at the College of Forestry and Range Science, Sudan University for Science and Technology. He has worked as an ACF at The Forestry National Corporation, Sudan, as Production Control Officer seconded to the Sudan Gum Arabic Company for two years. He has also worked in different capacities at the College of Forestry and Range Sciences, including Head Department of Silviculture, Dean of the Faculty, Head of the Research Unit and Secretary of University of Sudan Research Council. Dr Eldoma has worked as a coordinator for The Sudan Finland Forestry Program, and The Sudanese-Japanese Dry Land Research Group, sponsored by the Institute of Humanity and Nature, Kyoto, Japan. He has conducted several research projects and supervised many Postgraduate students at MSc and PhD levels. He is currently working as the Project Manager of the Natural Resources, Land Use Data Base and map for Darfur, implemented by the GAF AG Company based at Munich, Germany. Dr Eldoma has authored two books and 22 journal articles.

Sufyan Abd Elrzig Mohmmed Osman is Sudanese and works as the Head of the Agricultural Unit in the Khartoum Refinery Company in Khartoum-Sudan. He was awarded the Bachelor of Science in Forestry and Ranger Sciences, and Master of Science in Environment and Forestry from Sudan University of Science and Technology in 2002 and 2013 respectively. He has participated in many workshops inside and outside Sudan related to disaster management, quality control of water and wastewater, management of Petroleum installation, compost production and uses, proliferation of orchards, production of medicinal and aromatic plants, Cop 21 in France 2015.

Hind Abdalla Suliman Ali is Sudanese and graduated from the Faculty of Public and Environmental Health, University of Khartoum, and was awarded the BSc Honours in 2010. She was also awarded an MSc in Environmental Sciences, University of Khartoum in 2015. She worked as a part-time lecturer in Bahri University, Khartoum, and has participated in many workshops and seminars related to environmental problems in Sudan.