Res. Crop. **23** (2) : 473-479 (2022) DOI : 10.31830/2348-7542.2022.064
With three figures
Printed in India

Potential of low-salinity water utilization for watering the coast cultivation areas in the context of global warming

LE MY DUNG[1], NGUYEN THI TRANG THANH[2,*], HOANG PHAN HAI YEN[2], LUONG THI THANH VINH[2], NGUYEN THI HOA[1,2] AND PHAM VU CHUNG[2]

[1]*Geography Department, Hanoi National University of Education*
136 Xuan Thuy Street, Cau Giay District, Hanoi, Vietnam
(e-mail : thanhntt@vinhuni.edu.vn)

(Received : December 04, 2021/Accepted : April 18, 2022)

ABSTRACT

The coastal cultivation areas (CCAs) suffer to be affected by saltwater intrusion as a part of global warming. Low-salinity water (LSW) is considered as one of the effective alternative solutions for irrigation in water-scarce areas in the context of global warming. The main objective of this research was, therefore, to investigate the potential of using the LSW for watering the coastal sugarcane paddies in Tuy An District under the background of saline irrigation water. The research was deployed on three randomized blocks with sugarcane LK92-11, Uthong-11, and K83-29 varieties during the cultivation crop of 2018-19. Treatments included full freshwater irrigation and the LSW varying from 1.0 to 4.0 dS/m, respectively based on the drip irrigation system. The volume of irrigation water was equivalent to 100% of crop evapotranspiration. The daily crop evapotranspiration was simulated based on the APSIM-SUGAR model while the plant growth parameters such as mean number of living leaves, mean leaf area, stem diameter and sugarcane yield were investigated based on the Tukey test ($p \le 0.05$). The results indicate that the blending rate for irrigating with LSW and freshwater at 1.5 dS/m enhanced the plant growth parameters as well as crop yield while the blending rate for different irrigations varying from 2.0 to 4.0 dS/m recorded a decline of both the plant growth parameters and crop yield. Based on the findings, the blending rate for irrigating with LSW and freshwater at 1.5 dS/m enhanced high crop yield but was not significantly different compared to full freshwater irrigation.

Key words : Coastal cultivation, global warming, seawater intrusion, blending, adaptation

INTRODUCTION

Sugarcane (*Saccharum* L.) production in the CCAs has been severely affected by increases in the frequency and intensity of drought and saline intrusion (Chen *et al.*, 2017; Lee and Dang, 2018), leading to scarcity of irrigation water in recent years (Liu *et al.*, 2016; Anízio *et al.*, 2020; Gayathry *et al.*, 2021). Global warming leads to the increased intensity of saltwater intrusion and this is expected to have a threat to the CCAs around the world because of relatively low adaptive capacity but high vulnerability to natural hazards (Lira *et al.*, 2018; IPCC, 2019). According to the report of the Intergovernmental Panel on Climate Change (IPCC), the CCAs are concealed to be increasingly at the disaster risks in the background of global warming (IPCC, 2019; Dang *et al.*, 2021).

Global warming is expected to increase drought and saltwater intrusion (Baath *et al.*, 2017; Dang *et al.*, 2021), one of the main factors causing yield loss due to lack of water for irrigation (Liu *et al.*, 2016; Manzoor *et al.*, 2019), resulting in a series of socio-economic problems (Mansour *et al.*, 2016; Dang *et al.*, 2021). Globally, the low-salinity water (LSW) is known to be an extremely abundant resource with a volume of approximately 1.39 × 109 km3 and is as much as the freshwater resources (Chen *et al.*, 2017). Therefore, the LSW has been considered as an alternative resource for

[2]Geography Department, College of Education, Vinh University, 182 Le Duan Street, Vinh City Nghe An Province, Vietnam.

irrigation freshwater with high economic efficiency (Chen *et al.*, 2017; Dang, 2020). Knowing the usability of the LSW for irrigation in the CCAs where fresh water is becoming scarce (Lee and Dang, 2018; Simões *et al.*, 2018; Uke and Haliru, 2021), numerous studies have been explored widely and the successful field applications of the LSW for watering the sugarcane crops around the world in recent years (Lira *et al.*, 2018). For example, in Egypt, Mansour *et al.* (2016) used the LSW to irrigate wheat *Triticum aestivum* L. variety. The results indicate that subsurface drip irrigation has a preemptive effect on wheat grain and the percentage of the increase was 7.1 as compared with an automation controller irrigation system. Liu *et al.* (2016) studied the effects of the LSW on the grain yield of the winter wheat in the low plain of North China. Their experiment treatments deployed with no irrigation (T1), freshwater irrigation (T2), LSW irrigation (T3: 2.8 dS/m), and strongly saline water irrigation (T4: 8.2 dS/m). The results carry out that applying the LSW irrigation at the jointing stage of winter wheat is most promising to realize high yield and fresh irrigation water saving. Baath *et al.* (2018) evaluated the effects of the LSW in the various growth stages of the chile pepper plants. They designed the five irrigation water levels included 0.6, 3.0, 6.0, 8.0 and 10.0 dS/m. Their results point out that the chile pepper cultivars can be watered up to 3.0 dS/m. In Brazil, a study on the applicability of the LSW for watering sugarcane was explored by Lira *et al.* (2018). Randomized experimental designs were applied with the LSW treatments consisting of 0.5, 2.0, 3.5, 5.0 and 6.5 dS/m, corresponding to 100 of the crop evapotranspiration. Their results report that LSW can be reduced yield and stem dry weight of sugarcane.

As a result, the most applied solutions can include all LSW irrigation, the blending of LSW with fresh water, and the alternation of LSW with freshwater (Baath *et al.*, 2017; Lira *et al.*, 2018). Among the mentioned adapt solutions, the blending between LSW and freshwater has enhanced the better adapt solutions (Liu *et al.*, 2016; Mansour *et al.*, 2016). Numerous studies have been proposed the LSW in the range from 0.5 to 6.5 dS/m for watering sugarcane plants around the world (Liu *et al.*, 2016; Baath *et al.*, 2018; Lira *et al.*, 2018). The blending of LSW with freshwater is considered an effective solution with low cost (Wang *et al.*, 2019; Ning *et al.*, 2020). Moreover, the utilization of LSW for irrigation has an environmental advantage because it reduces the freshwater use requirement. However, no consensus on a fix ed LSW level has been reported. The main objective of this research was, therefore, to investigate the potential of using the LSW for watering the sugarcane cultivation paddies across Tuy An District under the impacts of saltwater intrusion.

MATERIALS AND METHODS

Study Area

Tuy An is a coastal district in the South Central of Vienam, which lies between 13°08'30"-13°22'00" N latitude and 109°05'30"-109°20'30" E longitude (Fig. 1). Its terrain consists of plains, hills, and sea with a coastline of approximately 45 km (Lee and Dang, 2018). The area has a monsoon tropical climate with the mean air temperature around 25.0 to 27.0 °C and maximum air temperature can be reach up to 38-40 °C, relative humidity approximately 85%, and mean annual rainfall up to 1800 mm (Lee and Dang, 2018). The climate has two distinct seasons including the rainy season lasts from September to the end of December and the dry season starts from January to the end of August. In the area, sugarcane commonly sows in the end of December and harvest in late of November (Lee and Dang, 2018). The main limitation of the area is that the irrigation use water is contaminated with salt during the dry season.

Method Approach

The research was exployed during the sugarcane growing seasons of 2018/19, designing a soil bed to sow sugarcane cuttings with a scheme of 8 rows x 3 plots, 35 cm in cutting pacings and 80 cm in row spacings at depth of roots approximately 15 cm from the soil surface (Fig. 2).

The irrigation water for system came from eight tanks with a volumn up to 5.0 m^3 for each. One was filled with fresh water (0.5 dS/m) and the second to sixth with LSW levels varying from (1.0-4.0 dS/m) (Table 1). To irrigate the sugarcane cuttings, drip irrigation

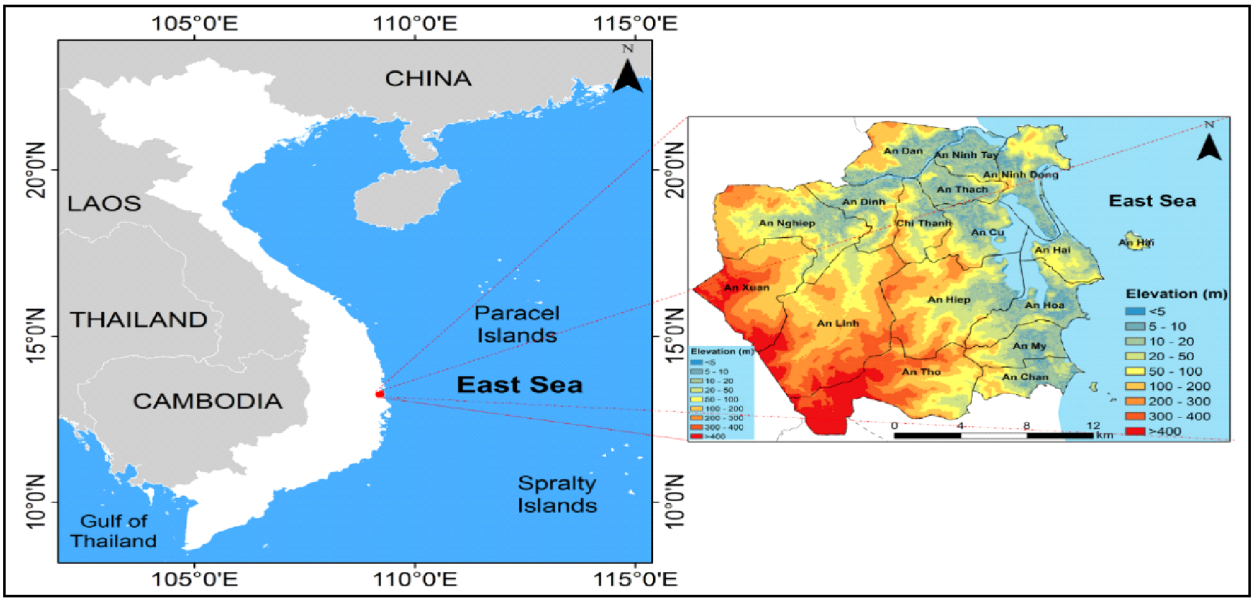

Fig. 1. Illustration of the study area.

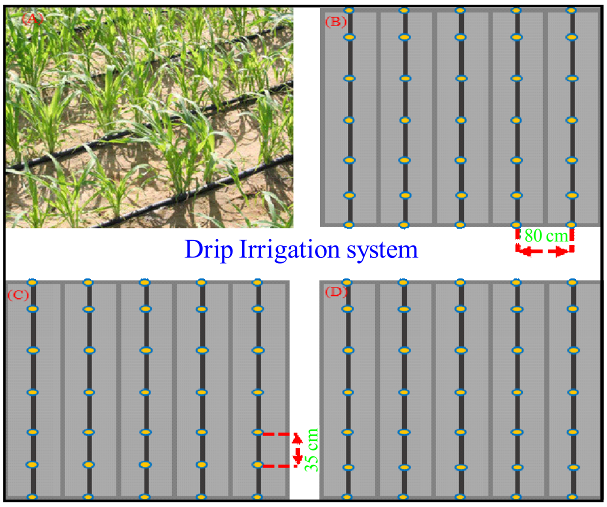

Fig. 2. Sugarcane sow practice in the study area with a) K83-29 variety, b) LK92-11 variety and c) Uthong-11 variety experimentes.

systems provide the amounts of mixed water equivalent to 100% of crop evapotranspiration in which the crop evapotranspiration was defined based simulating the APSIM-SUGAR model. Detail information of the APSIM-SUGAR crop model are described by Inman-Bamber (2016).

Based on cultivation practices in the area, sugarcane growers ploughed and loosened the soil surface before sowing, regular weeding, and sprayed pesticide consistent with local planting conventional practices. While pests are monitored following the guidelines of the Department of Agriculture and Rural Development (DARD) of Phu Yen Province and fertilizer application rate is also conducted in the same method as guided by DARD. The physicochemical properties of soil at three surveyed locations across the study area were collected and analyzed using the United States Department of Agriculture software (Jinquan *et al.*, 2020). Analysis show that the soil is classified as clay loam to silt loam with the percentages of each sample and soil water contents as electrical conductivity (ECw), field capacity (FC), total available soil moisture (FC-WP), total available water (TAW), permanent wilting points (PWP), hydraulic conductivity (K) and main physicochemical properties (K^+, Na^+, Ca^{2+}, Mg^{2+} and pH) were presented in Table 2. In addition, the chemical analysis of irrigation use water is presented in Tables 3 and nutrient elements of blended irrigation water also showed in Table 4.

RESULTS AND DISCUSSION

Analysis of the results of potential of using the low salt water (LSW) for watering the coastal sugarcane paddies at 3 specific locations in Tuy An District were conducted. Results show that the blending rate of LSW with fresh water at D3 level recorded a good growth in terms of the plant growth parameters compared to the blended rates (D5, D6, D7 and D8) but did not record a significant difference compared to the blending rates (D1 and D2). This means that the D3 irrigation level

Table 1. Blending of LSW with fresh water for watering sugarcane cuttings.

Design	Rates	Methods	Blended irrigation water levels
D1	100% fresh water	Full freshwater irrigation	0.5 dS/m
D2	90% fresh water and 10% LSW	90% of irrigations with fresh water and 10% with LSW	1.0 dS/m
D3	80% fresh water and 20% LSW	80% of irrigations with fresh water and 20% with LSW	1.5 dS/m
D4	70% fresh water and 30% LSW	70% of irrigations with fresh water and 30% with LSW	2.0 dS/m
D5	60% fresh water and 40% LSW	60% of irrigations with fresh water and 40% with LSW	2.5 dS/m
D6	50% fresh water and 50% LSW	50% of irrigations with fresh water and 50% with LSW	3.0 dS/m
D7	40% fresh water and 60% LSW	40% of irrigations with fresh water and 60% with LSW	3.5 dS/m
D8	30% fresh water and 70% LSW	30% of irrigations with fresh water and 70% with LSW	4.0 dS/m

Table 2. Physicochemical properties of the soil at three surveyed locations across the study area.

Determination	Three surveyed locations		
	ST1	ST2	ST3
Coarse sand (%)	7.6	8.7	5.1
Fine sand (%)	19.4	18.9	21.9
Silt (%)	57	43.4	55
Clay (%)	34	29	18
Textture	Clay loam	Clay loam	Silt loam
FC (% vol)	37	39	41
PWP (% vol)	28	19	21
K (mm/d)	13	3.0	3.4
ECw (dS/m)	0.28	0.33	0.29
K^+(ppm)	22	19	24
Na^+(ppm)	29	18	30
Ca^{2+}(ppm)	37	41	33
Mg^{2+}(ppm)	28	31	29
Cl^-(meq/100 g soil)	1.1	1.5	2.0
pH	5.7	6.3	5.9

ECs: soil electrical conductivity; FC: field capacity; PWP: permanent wilting point; K: hydraulic conductivity.

Table 4. Nutritional ingredients (ppm) of blended irrigation water for sugarcane plants.

Irrigation water	N	P	K	Fe	Zn	Mn
D1	3.6	0.24	7.4	0.16	0.18	0.05
D2	24.6	0.39	9.6	0.18	0.98	0.20
D3	24.8	0.40	9.8	0.20	1.02	0.22
D4	25.2	0.42	10.0	0.22	1.04	0.23
D5	25.5	0.44	10.2	0.24	1.06	0.24
D6	25.9	0.56	10.4	0.26	1.08	0.25
D7	26.1	0.48	10.6	0.28	1.10	0.27
D8	26.4	0.50	10.8	0.29	1.12	0.28

enhanced the good growth of the plant growth parameters as well as final sugarcane yield. These findings support those reported by Anízio *et al.* (2020) that both leaf area and stem diameter decreased with an increase in the blended rate of LSW. In similar study, Lira *et al.* (2018) reported that plant growth parameters decreased linearly with increased the blended rate of LSW and fresh water. They stated that the blending of the LSW and fresh water at 1.5 dS/m was not high enough to

Table 3. Chemical ingredients of blended irrigation water to irrigate sugarcane cuttings.

Irrigation water	pH	Blended water levels	Soluble ions meq/L							
			K^+	Na^+	Ca^{2+}	Mg^{2+}	CO_3^-	HCO_3^-	CL^-	SO_4^{2-}
D1	7.3	0.5	0.23	3.83	1.42	2.20	0.06	2.6	4.2	0.6
D2	7.2	1.0	0.26	28.05	4.41	3.75	0.03	8.1	18.9	7.9
D3	7.0	1.5	0.27	29.27	4.65	3.80	0.04	8.3	19.7	8.0
D4	6.8	2.0	0.29	29.45	4.81	3.85	0.05	8.4	20.4	8.1
D5	6.6	2.5	0.30	29.62	5.08	3.90	0.06	8.5	20.9	8.3
D6	6.4	3.0	0.31	29.81	5.22	3.95	0.07	8.6	21.3	8.5
D7	6.3	3.5	0.33	30.03	5.43	3.99	0.08	8.7	21.9	8.7
D8	6.2	4.0	0.35	30.21	5.61	4.03	0.09	8.8	22.4	8.9

Plant growth parameters were analyzed based on the Tukey test with $P \leq 0.05$.

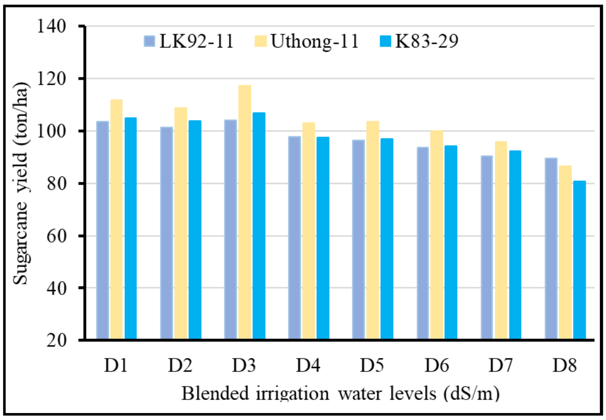

Fig. 3. Obtained crop yield for three sugarcane varieties correspond to the blending rates of LSW with fresh water.

cause a deleterious effect on the growth process of sugarcane. However, watered sugarcane with D2 level reduced its yield by 2.05% compared to irrigate full fresh water but applying D8 level reduced average sugarcane yield up to 15.08% (Table 5).

Data nalysis show that sugarcane irrigated with the blend rate of LSW and fresh water at D3 level obtained a high yield compared to the blend rates varying from D4 to D8 (Table 6). It implies that the blend rate of LSW and fresh water at D3 is suitable for the good growth of sugarcane compared with other blended ratios of applied irrigation water (Fig. 3). A reduction in leaf area and stem diameter of sugarcane plants watered with high blending rate was also stated by Anízio *et al.* (2020). Their research reports that high rate of blended saline also reduced plant height. Based on the analysis, it can be stated that crop yield is dominated by the blended rates of applied irrigation water. A similar study by Simões *et al.* (2018) also reported that the crop yield of sugarcane decreased with the blending rate of LSW with fresh water over 3.0 dS/m. For crop yield, the blending rate of LSW with fresh water at D3 level recorded a good growth in terms of the plant growth

Table 5. Plant growth parameters analyzed under the blending rates for different irrigations varying from 0.5 to 4.0 dS/m across three observed locations.

Variety	Blended rates of LSW and freshwater (dS/m)							
	D1	D2	D3	D4	D5	D6	D7	D8
Mean leaf area (cm²)								
LK92-11	374.5a	375.8a	376.9b	371.9a	348.9b	319.4b	287.2b	268.4a
Uthong-11	386.7a	387.1b	387.8a	377.4b	347.2a	324.9b	301.7a	283.5a
K83-29	362.9b	361.0b	361.7a	362.4a	289.0b	277.8a	267.6a	256.4b
Mean number of living leaves								
LK92-11	8.0a	8.0a	8.1b	7.9a	7.6b	7.4a	7.1b	6.9a
Uthong-11	8.1a	8.1b	8.2a	8.0b	7.8b	7.6a	7.3b	7.1a
K83-29	8.3b	8.2a	8.5b	8.3b	8.0a	7.8b	7.4a	7.2b
Stem diameter (cm)								
LK92-11	27.6b	27.7a	27.8b	26.3b	25.7a	24.8b	23.9a	22.4b
Uthong-11	28.6a	28.4a	28.5b	27.1a	25.5a	23.7a	21.4b	20.8a
K83-29	29.2b	29.9b	30.1a	29.7b	28.4b	25.9b	22.1b	21.1b

Means followed by the same letters in the columns and same letters in the rows do not differ from each other by Tukey test ($P \leq 0.05$).

Table 6. Sugarcane yield (t/ha) observed under the blending rates for different irrigations varying from 0.5 to 4.0 dS/m across three observed locations.

Variety	Blended rates of LSW and freshwater (dS/m)							
	D1	D2	D3	D4	D5	D6	D7	D8
LK92-11	51.9a	50.7b	50.1b	48.9a	48.1b	46.8b	45.1a	44.8a
Uthong-11	55.8a	54.3a	53.6b	51.4a	51.7a	49.9b	47.9a	43.2b
K83-29	52.4b	51.8b	49.9a	48.7b	48.5a	47.1a	46.1b	40.4b

Figures followed by the same letters in the columns and same letters in the rows do not differ from each other by Tukey test ($P \leq 0.05$).

parameters as well as crop yield than those obtained when the blended rate of LSW with fresh water varying from D4 to D8 level but did not record a significant difference between the blending rate of LSW with fresh water varying from D1 to D2 levels. Specifically, the mean cassava yield can be achieved 109.3 ton/ha at D3 level (1.5 dS/m) while the blending rate at D1 level (reached approximately 106.6 ton/ha). whereas the blending rates varying from D4 to D8 levels a mean decreased trend around 2.38 to 14.93%, respectively was recorded (Fig. 3).

CONCLUSION

The research investigated the potential of using the LSW for watering the sugarcane paddies across Tuy An District in the context of scarce irrigation fresh water. The research was conducted with sugarcane LK92-11, Uthong-11, and K83-29 varieties during the cultivation crop of 2018-19. Treatments based on the blending rates of LSW with fresh water varying from 0.5 to 4.0 dS/m through the drip irrigation system. The results indicated that high crop yield obtained when the blending rate of LSW with fresh water at 1.5 dS/m while it was not significantly different compared to the blending rate varying from 0.5 to 1.0 dS/m. However, the blending rates varying from 2.0 to 4.0 dS/m decreased gradually the plant growth parameters as well as crop yield and especially a significant reduction was observed up to 15.12% when the blending rate at 4.0 dS/m.

REFERENCES

Anízio, H. G. N., Ênio, F., de F. S., José, E. F. M., Larissa, G. L. A., Weliston, O. and Cutrim, C. F. L. (2020). Water potential, biochemical indicators and yield of sugarcane irrigated with brackish water and leaching. *Rev. Bras. Eng. Agríc. Ambient.* **24** : 312-18.

Baath, G. S., Shukla, M. K., Bosland, P. W., Steiner, R. L. and Walker, S. J. (2017). Irrigation water salinity influences at various growth stages of *Capsicum annuum*. *Agric. Water Manag.* **179** : 246-53.

Chen, L. J.; Li, C. S.; Feng, Q.; Wei, Y. P.; Zheng, H.; Zhao, Y.; Feng, Y. J. and Li, H. Y. (2017). Shifts in soil microbial metabolic activities and community structures along a salinity gradient of irrigation water in a typical arid region of China. *Sci. Total Environ.* **598** : 64-70.

Dang, T. A. (2020). Assessing the effectiveness of drip irrigation combined with agricultural mulches on the performance of tomato (*Lycopersicon esculentum*) under water constraint conditions of Lam Dong Province, Vietnam. *Res. Crop.* **21** : 712-18.

Dang, T. A., Nguyen, V. H. and Mai, P. N. (2021). Utilizing rainfed supply and irrigation as a climate variability adaptation solution for coastal lowland areas in Vietnam. *Agr. Nat. Resour.* **55** : 485-95.

Gayathry, G., Shanmuganathan, M., Ravichandran, V., Anitha, R. and Babu, C. (2021). Evaluation of quality attributes of powdered jaggery from promising sugarcane varieties (*Saccharum* sp. hybrid). *Res. Crop.* **22** : 425-32.

Inman-Bamber, N. G., Jackson, P. A., Stokes, C. J., Verrall, S., Lakshmanan, P. and Basnayake, J. (2016). Sugarcane for water-limited environments: enhanced capability of the APSIM sugarcane model for assessing traits for transpiration efficiency and root water supply. *Field Crop Res.* **196** : 112-23.

IPCC (2019). Climate Change and Land: An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Electronic copies of this report are available from the IPCC website www.ipcc.ch.

Jinquan, L., Ming, N., Jeff, R. P., Andrew, B. and Elise, P. (2020). Soil physico-chemical properties are critical for predicting carbon storage and nutrient availability across Australia. *Environ. Res. Letters.* **15** : 1-15.

Lee, S. K. and Dang, T. A. (2018). Application of AquaCrop model to predict sugarcane yield under the climate change impact: A case study of Son Hoa district, Phu Yen province in Vietnam. *Res. Crop.* **19** : 310-14.

Lira, R. M. de; Silva, E. de F. F. e; Simões Neto, D. E.; Santos Junior, J. A.; Lima, B. L. de C. and Silva, J. S. da. (2018). Growth and yield of sugarcane irrigated with brackish water and leaching fractions. *Revista Brasileira de Engenharia Agrícola e Ambiental.* **22** : 170-75.

Liu, X., Feike, T., Chen, S., Shao, L., Sun, H. and Zhang, X. (2016). Effects of saline irrigation on soil salt accumulation and grain yield in the winter wheat-summer maize double cropping system in the low plain of North China. *J. Integr. Agric.* **15** : 2886-898.

Mansour, H. A., Abd El-Hady, M., Bralts, V. F. and Engel, B. A. (2016). Performance automation controller of drip irrigation systems using saline water for wheat yield and water productivity in Egypt. *J. Irrig. Drain. Eng.* **142** : 5016005.

Manzoor, M. Z., Sarwar, G., Aftab, M., Tahir, M. A., Sabah, N. and Zafar, A. (2019). Role of leaching fraction to mitigate adverse effects of saline water on soil properties. *J. Agric. Res.* **57** : 275-80.

Ning, S., Zhou, B., Wang, Q. and Tao, W. (2020). Evaluation of irrigation water salinity and leaching fraction on the water productivity for crops. *Int. J. Agric. Bio. Eng.* **13** : 170-77.

Simões, W. L., Calgaro, M., Guimarães, M. J. M., Oliveira, A. R. and dez Pinheiro, M. P. M. A. (2018). Sugarcane crops with controlled water deficit in the sub-middle São Francisco valley, *Brazil. Revista Caatinga.* **31** : 963-71.

Uke, O. D. and Haliru, M. (2021). Salinity study of the soils of Fadama farms, Sokoto, Nigeria. *Farm. Manage.* **6** : 1-7.

Wang, T. N., Xu, Z. H. and Pang, G. B. (2019). Effects of irrigating with brackish water on soil moisture, soil salinity, and the agronomic response of winter wheat in the Yellow River Delta. *Sustainability* **11** : doi.org/10.3390/su11205801.