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A Narrative Review of Saline Land: Challenges and Management Practices for Agricultural Development in Indonesia

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ABSTRACT
Land salinity is one of the challenges in the development of the agricultural sector as it can negatively affect crop growth and yield. High salt content in the soil can have many negative impacts on soil fertility and crop productivity. Therefore, various saline land management technologies are needed to increase land potential and support agricultural activities optimally. The method used is Narrative Literature Review that synthesises and describes various relevant and accurate secondary research and data. This method also uses approaches that have been carried out and analyses and descriptions in existing research. The aim is to provide applicable saline land management recommendations to support increased agricultural productivity on saline land. The results and conclusions in this study show that the application of various practices on saline land can reduce salinity, improve soil quality and fertility, and increase crop productivity on saline land.

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INTRODUCTION

The continuous growth of Indonesia's population will drive the demand for land for various purposes, such as housing, industry, and other infrastructure. According to Noviwiyanah and Yudhistira (2024), this condition can trigger land conversion that has the potential to threaten the sustainability of the agricultural sector. In fact, population growth has a direct impact on the increase in national food demand.

In addition, the reduction in productive land area due to soil degradation, either due to erosion or agricultural intensification, is also an obstacle in meeting food needs. Therefore, efforts are needed to utilise marginal land as an alternative to increase food production amid these various challenges. One type of marginal land that has not been optimally utilised for agriculture is saline land. This land has a high concentration of dissolved salts, which can cause various negative impacts on crops, including reduced productivity. Although saline land has limitations for cultivation, this type of land is quite common in Indonesia, especially in coastal areas, lowlands, and poorly managed irrigation areas. Saline land has the potential to be an alternative resource if managed with the right management strategy.

Land that has been considered unproductive can be optimised through the implementation of effective saline land management. However, many farmers in Indonesia still lack adequate knowledge about this. Therefore, this study aims to provide practical recommendations for saline land management for farmers so that the land can be optimally utilised for agricultural cultivation. This study also seeks to offer adaptive management strategies and appropriate cultivation technologies to enhance the productivity of saline land. With the right approach, saline land can not only support national food security but also expand the agricultural production base amid limited productive land.

MATERIALS AND METHOD

This study is a narrative literature review aimed at summarizing and analyzing existing literature related to soil salinity in Indonesia, including its extent, major causes, crop responses, and management practices. Relevant literature was collected from several scientific databases, including ScienceDirect, Google Scholar, and PubMed. Articles included in this review were scientific publications (research articles and review papers), published between 2015 and 2025, written in English or Indonesian, and available in full-text format. However, older articles published before 2015 were also included if they were considered highly relevant or foundational to the topic. The selection process was carried out manually by reviewing the titles, abstracts, and full texts to ensure relevance to the review topic. Irrelevant, duplicate, or inaccessible articles were excluded.

DISCUSSION

Saline Land Overview

Saline land is a type of land with sodium content in the soil exceeding the critical threshold tolerable by plants, characterised by high concentrations of easily soluble salts. The presence of certain ions such as Na^+, Mg^{2+}, K^+, Cl^-, Ca^{2+}, NO_3^-, SO_4^{2-}, and HCO_3^- plays a role in increasing soil salinity (Gondek et al., 2020). Additionally, the presence of Na^+ ions in the soil, sodium content in the exchangeable cation complex, and electrical conductivity (EC) can influence soil salinity levels (Kusumiyati et al., 2014; Purwaningrahayu & Taufiq, 2018; Muharam & Saefudin, 2016). Soil salinity can be measured based on electrical conductivity (EC) values, as these values are related to the total amount of dissolved ions or the total amount of dissolved salts in the soil (Xie et al., 2021). Saline soils are characterised by EC values >4, soil pH <8.5, and exchangeable sodium <15% (Stavi et al., 2021). Based on EC values, saline soils are classified into five categories (Table 1): non-saline soils, slightly saline soils, saline soils, strongly saline soils, and extremely saline soils (Brown et al., 1954).

Table 1. Classification of saline soils based on EC values and their effects on plants

Salinity classification	EC ($mS.cm^{-1}$)	Effect on Crop yield
Non-saline soils	0-2	No crops affected
Slightly saline soils	2-4	Affected to sensitive crop
Saline soils	4-8	Many crops affected
Strongly saline soils	8-16	Only crops with high tolerance
Extremely saline soils	>16	A limited number of high tolerance crops

Saline Land Distribution in Indonesia

The distribution of saline land in Indonesia is not yet known with certainty because there has been no spatial inventory (Karolinoerita & Yusuf, 2020). However, Masganti et al. (2022) estimate that the area of saline land in Indonesia has reached 0.6 million ha. Sukarman et al. (2018) estimated the area of landforms vulnerable to increased salinity in Indonesia to be around 12 million ha, or approximately 6.2% of Indonesia's land area. These landforms include marine, fluvio-marine, and alluvial (Table 2). Saline soil is generally found in marine and fluvio-marine landforms because these landforms have sloping slopes (Hasmunir, 2017). Marine landforms are formed by the activity of seawater and can be found throughout most of Indonesia, while fluvio-marine landforms are formed by the activity of seawater and rivers and are more commonly found in Kalimantan and Sumatra (Dewadaru & Saputro, 2014; Wulan et al., 2016; Mulyani et al., 2022).

Table 2. Area of landforms vulnerable to salinity increase

Landform	Sub-landform	Area (Ha)
Aluvial	Alluvial basin (lacsustrine)	1.007.857
Fluvio-marin	Delta or estuarine plain	2.225.391
Marin	Tidal flats	7.312.813
	Coastal area	1.474.924
Total		12.020.985

Factors Affecting Soil Salinity

Salinity in soil can be caused by various factors. Generally, saline land can be found in areas with arid and semi-arid moisture regimes (Gopalakrishnan & Kumar, 2020). Areas with these two moisture regimes have lower rainfall than evaporation rates. This leads to salt accumulation and prevents base leaching in the soil (Karolinoerita & Yusuf, 2020). Additionally, soil salinity can be influenced by the distance from land to sea (Fu et al., 2020). High soil salinity is primarily found near seawater, especially in coastal areas (Sui et al., 2022). One cause of salinity in coastal areas is seawater intrusion, or the entry of seawater into the soil or groundwater due to a decrease in groundwater level or an increase in sea level. This intrusion can increase salt concentration in the soil and cause soil salinity (Setiawan, 2020). Eswar et al. (2021) reported that soil in coastal areas contains salt concentrations of 0.5–2.0%.

Soil salinity can also be influenced by the use of irrigation water containing salt due to seawater intrusion and poor land drainage systems, allowing salt-containing water to enter irrigation channels. The discharge of liquid waste from industries containing salt into irrigation channels can serve as an additional source of salt ions, increasing soil salinity (Jiang et al., 2021). An example is the case in Rancaekek, Bandung Regency (Masganti et al., 2022). Additionally, soil salinity can be influenced by geological conditions and parent soil materials. Soils derived from parent materials rich in salt minerals tend to have higher salinity levels (Erfandi & Rachman, 2011).

Effects of Soil Salinity on Crop Growth and Yield

Soil salinity is often associated with high concentrations of Na^+ and Cl^- ions in the soil (Stavi et al., 2021). When these two ions are absorbed by plants in excess of their threshold requirements, they can cause cytotoxity that can disrupt growth and even cause plant death. Excessive Na^+ ions can also reduce the availability and interfere with the absorption of other essential ions such as K^+, Ca^{2+}, and Mg^{2+} due to cation competition (Atta et al., 2019; Yildiz et al., 2020; Atta et al., 2021). In addition to affecting nutrient uptake, high Na^+ ion content in soil can also damage soil physical properties, such as causing clay dissolution and increasing soil bulk density, which ultimately reduces crop yield (Karolinoerita & Yusuf, 2020; Sabir et al., 2021).

Salinity stress also affects the uptake of micronutrients essential for root growth, such as Ca, Mg, Fe, and Zn. The reduced availability of these nutrients can inhibit growth and impair the roots' ability to absorb nutrients optimally (Robin et al., 2016; El Sabagh et al., 2021; Arif et al., 2019). In general, salinity can reduce plant growth and yield through three main mechanisms: reduced osmotic potential, ionic toxicity, and nutrient uptake imbalance by plants (Darwish et al., 2009; Akter & Oue, 2018). Its impacts are highly significant on various agricultural crops, such as rice, where yields can decrease by 30–50% (Eynard et al., 2005; Hoang et al., 2015), corn by 50–60% (Zorb et al., 2018), peanuts by 25–50% (Otitoloju, 2014; Zorb et al., 2018), and sugarcane by 5–60% (Plaut et al., 2000; Rao et al., 2015; Kumar et al., 2023).

Saline Land Management Practices

Soil Salt Leaching

Salt leaching is an effective method for managing salt levels in soil. The principle of this method is to transfer salt from the upper layers to deeper layers of soil. Salt leaching is carried out using water with low electrolyte content, thereby preventing excessive salt accumulation that can damage plants. Therefore, the success of this technique depends heavily on the availability of water and a good drainage system (Shankar & Evelin, 2019).

Salt leaching in saline soil can be carried out using soaking and spraying techniques. Soaking can be done by continuously or intermittently soaking the soil. Continuous soaking allows the salt leaching process to occur more quickly, while intermittent soaking requires more time but uses less water. Intermittent soaking is more effective on soils with a hard layer, while continuous soaking is more effective on fine soils. Meanwhile, spraying is done on land where soaking is not possible. However, this technique requires more energy and higher costs than soaking techniques (Sanga et al., 2024).

Soil Amendments

Soil amendments are defined as materials added to soil to improve its physical, chemical, and biological properties. Dariah et al. (2015) state that soil amendments are not classified as fertilizers even though they contain nutrients, because their content is relatively low and therefore cannot meet the nutritional needs of plants. In Indonesia, soil amendments that are applied must meet the minimum technical requirements specified in Ministry of Agriculture Regulation No. 261/KPTS/SR.310/M/4/2019. This is to ensure their effectiveness in improving soil quality.

The addition of soil amendments to saline soil can have a positive effect on soil properties as well as plant growth and yield. Soil amendments applied to saline soil can increase soil pH by 5–17% and crop yield by 9–57% (Zhang et al., 2023). Soil amendments derived from organic materials such as biochar, animal manure, and straw have a basic pH, so when applied to saline soil, they can increase soil pH. Additionally, soil amendments derived from organic materials have pH-buffering capacity and contain carboxyl and hydroxyl groups that can react with H^+ ions, thereby increasing soil pH (Xu et al., 2012). Increased soil pH is consistent with improved nutrient availability in the soil, as soil pH determines nutrient availability (Kennedy, 2022).

Crop Rotation

Crop rotation is one of the most effective cultivation techniques for saline soils. Salt-tolerant crops are planted during the dry season, while salt-sensitive crops are planted during the rainy season (Cuevas et al., 2019). The selection of these crop types is based on the fact that salinity increases during the dry season, so salt-tolerant crops are planted during the dry season (Bhuyan et al., 2023). The results of Ahmed et al. (2019) indicate that crop rotation on saline land can improve soil quality, reduce the negative impacts of salinity, and provide better income for farmers. Table 3 shows the types of plants that are susceptible and tolerant to various levels of soil salinity (Jamalkhan et al., 2010).

Tabel 3. Tolerance of several plant species to various levels of salinity

Sensitive (0-4 $mS.cm^{-1}$)	Moderately tolerant (4-6 $mS.cm^{-1}$)	Tolerant (6-8 $mS.cm^{-1}$)	Highly tolerant (8-12 $mS.cm^{-1}$)
Onion CarrotLettuce Groundpeanut Pepper Strawberry	Maize Sorghum Soybean	Wheat Sunflower	Barley Asparagus

Mulching

Mulch is a soil cover commonly used in agricultural cultivation. Mulch can be made from organic and inorganic materials. Organic mulch comes from easily decomposable materials such as straw, sawdust, plant biomass, and animal manure. Meanwhile, inorganic mulch is made from materials that are difficult to decompose, such as plastic. Applying mulch to soil can serve to maintain soil temperature and moisture, prevent water loss, suppress weed growth, prevent erosion, reduce nutrient leaching, and maintain nutrient availability in the root zone of plants, thereby enhancing plant growth and yield as well as improving water use efficiency (Kishore et al., 2022; Qiu et al., 2020; Yu et al., 2018). Not only that, the use of mulch has also been found to have positive effects when applied to saline soils (Alharbi, 2017). Mulching is known to reduce soil salinity by decreasing evaporation and salt movement toward the surface (Koriyev et al., 2025; Zhao et al., 2014). This aligns with the findings of Abd El-Mageed et al. (2016), who reported that mulching reduces salt accumulation in the root zone of plants.

Research on the use of various types of mulch to control soil salinity has been extensively conducted. The use of straw mulch is effective in reducing soil salinity and salt content, as well as improving corn and soybean yields (Li et al., 2023; Song et al., 2025; Purwaningrahayu & Taufiq, 2018). The application of plastic mulch can increase soil moisture, reduce salinity, and improve water use efficiency by plants. Plastic mulch can significantly reduce soil salinity at a depth of 0–100 cm and increase cereal crop yields (Zhang et al., 2018). Wang et al. (2022) combined the use of animal manure and plastic as mulch. The results showed that this combination significantly increased the growth and yield of corn and barley. Additionally, the combination reduced soil bulk density, increased organic matter, total nitrogen, and phosphorus availability in saline soil.

Salt-Tolerant Varieties

The use of salt-tolerant varieties is one of the practical technologies in managing saline land because it can be directly applied by farmers. These varieties have the ability to grow and produce optimally even in soil with high salt content. This is important for increasing agricultural productivity in marginal lands affected by salinity (Hairmansis, 2020). Utilizing salt-tolerant varieties allows for increased land productivity without requiring major changes to soil properties. This is important because improving soil characteristics is often a lengthy and costly process. Salt-tolerant varieties can also significantly reduce dependence on external inputs such as chemical fertilizers, soil amendments, and other saline land management technologies. Some salt-tolerant varieties include Inpari 34 Salin Agritan for rice (Anindyajati et al., 2021), Pacakka for maize (Dachlan et al., 2013), and Anjasmoro for soybeans (Putri et al., 2017).

CONCLUSION

The utilization of marginal land, such as saline land needed to ensure the continued development of agriculture in Indonesia, because it has been estimated that saline land has wide distribution, approximately 0.6 million hectares. Utilizing saline land without proper management can have many negative impacts on plant growth. Therefore, management practices are needed to manage saline land effectively to overcome these challenges. Implementing soil salt leaching, soil amendment, mulching, crop rotation, and salt-tolerant varieties are among the strategies that can mitigate the adverse effects of salinity. By adopting these maangement practices, it is possible to optimize the use of saline soils and contribute to sustainable agricultural development in Indonesia

REFERENCES

1. Abd El-Mageed, T. A., Semida, W. M., & Abd El-Wahed, M. H. 2016. Effect of mulching on plant water status, soil salinity and yield of squash under summer-fall deficit irrigation in salt affected soil. *Agricultural Water Management*, *173*, 1-12.
2. Ahmed, K., Qadir, G., Nawaz, M. Q., Sarfraz, M., Rizwan, M., Zaka, M. A., & Hussain, S. 2019. Feasibility of different crop rotations for cultivation in salt affected soils. *Acta agriculturae Slovenica*, *114*(1), 21-31.
3. Akter, M., & Oue, H. 2018. Effect of saline irrigation on accumulation of Na+, K+, Ca2+, and Mg2+ ions in rice plants. *Agriculture*, *8*(10), 1-16.
4. Alharbi, A. 2017. Effect of mulch on soil properties under organic farming conditions in center of saudi arabia. International Scientific Journal Mechanization in Agriculture, 4, 161-167.

5. Anindyajati, A. D., Purwoko, B. S., Dewi, I. S., & Suwarno, W. B. (2021). Respon Galur-galur Harapan Padi Sawah Dihaploid terhadap Salinitas pada Fase Bibit. *Jurnal Agronomi Indonesia*, *49*(3), 219-228.
6. Arif, M. R., Islam, M. T., & Robin, A. H. K. 2019. Salinity stress alters root morphology and root hair traits in *Brassica napus*. *Plants*. 8 (7), 1-14.
7. Atta, K., Karmakar, S., Dutta, D., Pal, A. K., & Jana, K. 2019. Comparative physiology of salinity, drought and heavy metal stress during seed germination in ricebean [*Vigna umbellata (Thunb.) Ohwi and Ohashi*]. J. Crop Weed, 15 (3), 145–149.
8. Atta, K., Pal, A. K., & Jana, K. 2021. Effects of salinity, drought and heavy metal stress during seed germination stage in ricebean [*Vigna umbellata (Thunb.) Ohwi and Ohashi*]. *Plant Physiol Rep*. 26, 109–115.
9. Bhuyan, M. I., Supit, I., Mia, S., Mulder, M., & Ludwig, F. 2023. Effect of soil and water salinity on dry season boro rice production in the south-central coastal area of Bangladesh. *Heliyon*, *9*(8), 1-15.
10. Brown, J. W., Hayward, H. E., Richards, A., Bernstein, L., Hatcher, J. T., Reeve, R. C., & Richards, L. A. 1954. Diagnosis and improvement of saline and alkali soils. United States Department of Agriculture, Agriculture handbook.
11. Cuevas, J., Daliakopoulos, I. N., del Moral, F., Hueso, J. J., & Tsanis, I. K. 2019. A review of soil-improving cropping systems for soil salinization. *Agronomy*, *9*(6), 1-22.
12. Dachlan, A., Kasim, N., & Sari, A, K. 2013. Uji ketahanan salinitas beberapa varietas jagung (*Zea mays* L.) dengan menggunakan agen seleksi NaCl. *Biogenesis*. 1(1), 9-17.
13. Dariah, A., Sutono, S., Nurida, N. L., Hartatik, W., & Pratiwi, E. 2015. Pembenah tanah untuk meningkatkan produktivitas lahan pertanian. *Jurnal sumberdaya lahan*, *9*(2), 67-84.
14. Darwish, E., Testerink, C., Khalil, M., El-Shihy, O., & Munnik, T. 2009. Phospholipid signaling responses in salt-stressed rice leaves. *Plant Cell Physiology*, 50(5), 986-997.
15. Dewadaru, D. P., & Saputro, S. 2014. Kajian morfologi pantai di pantai slamaran Kabupaten Pekalongan Semarang: J Oceanography 3: 105-123.
16. El Sabagh, A., Islam, M. S., Skalicky, M., Ali Raza, M., Singh, K., Anwar Hossain, M., ... & Arshad, A. 2021. Salinity stress in wheat (*Triticum aestivum* L.) in the changing climate: Adaptation and management strategies. *Frontiers in Agronomy*, *3*, 661932, 1-20.
17. Erfandi, & Rachman, A. (2011). Pengelolaan Lahan dan Tanaman Padi di Lahan Salin. *Jurnal Sumberdaya Lahan*, 16(2), 83–95.
18. Eswar, D., Karuppusamy, R., & Chellamuthu, S. 2021. Drivers of soil salinity and their correlation with climate change. Environmental Sustainability, 50, 310-318.
19. Eynard, A., Lal, R., & Wiebe, K. 2005. Crop response in salt-affected soils. *J. Sustain. Agric*. 27, 5–50.
20. Fu, Z., Wang, P., Sun, J., Lu, Z., Yang, H., Liu, J., ... & Li, T. 2020. Composition, seasonal variation, and salinization characteristics of soil salinity in the Chenier Island of the Yellow River Delta. *Global Ecology and Conservation*, *24*, 1-11.
21. Gondek, M., Weindorf, D. C., Thiel, C., & Kleinheinz, G. 2020. Soluble Salts in Compost and Their Effects on Soil and Plants: A Review. Compost Science & Utilization, 28(2), 59-75,
22. Gopalakrishnan, T., & Kumar, L. 2020. Modeling and mapping of soil salinity and its impact on paddy lands in Jaffna Peninsula, Sri Lanka. *Sustainability*, 12, 8317.
23. Hairmansis, A. 2020. Pengembangan varietas unggul padi untuk lahan terdampak salinitas. *Jurnal Pangan*, *29*(2), 161-170.
24. Hasmunir H. 2017. Materi pembelajaran geomorfologi untuk program studi pendidikan geografi. J Pendidik Geosfer 2: 9-21.
25. Hoang, T. M., Moghaddam, L., Williams, B., Khanna, H., Dale, J., & Mundree, S. G. 2015. Development of salinity tolerance in rice by constitutive-overexpression of genes involved in the regulation of programmed cell death. *Frontiers in plant science*, *6*(175), 1-14.
26. Jamalkhan, M., Jan, M., & Arif, M. (2010). Management of saline and sodic soils through cultural practices and gypsum. *Journal of agricultural science*. 89(1), 81-86.
27. Jiang, J., Zhai, D., Zhang, C., & Ma, J. 2021. Influence of saline water irrigation on root distribution, wheat yield, and soil salinity. *Journal of Irrigation and Drainage Engineering*. 147(4), 04021005.
28. Karolinoerita, V., & Yusuf, W. A. 2020. Salinisasi lahan dan permasalahannya di Indonesia. *Jurnal Sumberdaya Lahan*, 14(2), 91-99.
29. Kennedy, S. O. 2022. Soil pH and its impact on nutrient availability and crop growth. *International Journal of Geography, Geology, and Environment*, 4(2), 236-238.
30. Kishore, G., Babu, B. M., and Mattaparti, L. D. 2022. Influence of plastic mulching and irrigation levels on soil temperature, moisture and water use efficiency of tomato crop (*Solanum lycopersicum*). *Int. J. Plant Soil Sci*, 34(20), 277–282.

31. Koriyev, M., Mirzahmedov, I., Boymirzaev, K., & Juraev, Z. 2025. Effects of mulching, terracing, and efficient irrigation on soil salinity reduction in Uzbekistan's Fergana Valley. *Cogent Food & Agriculture*, *11*(1), 2449201.
32. Kumar, R., Dhansu, P., Kulshreshtha, N., Meena, M. R., Kumaraswamy, M. H., Appunu, C., ... & Pandey, S. K. 2023. Identification of salinity tolerant stable sugarcane cultivars using AMMI, GGE and some other stability parameters under multi environments of salinity stress. *Sustainability*, *15*(2), 1-19.
33. Kusmiyati, F., Sumarsono., & Karno. 2014. Pengaruh perbaikan tanah salin terhadap karakter fisiologi *Calopogonium mucunoides*. *Pastura*, 4(1), 1-6.
34. Li, M.; Wang, W.; Wang, X.; Yao, C.; Wang, Y.; Wang, Z.; Zhou, W.; Chen, E.; Chen, W. Effect of straw mulching and deep burial mode on water and salt transport regularity in saline soils. *Water*, 15, 3227, 1-18.
35. Masganti, M., Abduh, A. M., Alwi, M., Noor, M., & Agustina, R. (2022). Pengelolaan lahan dan tanaman padi di lahan salin. *Jurnal Sumberdaya Lahan*, *16*(2), 83-95.
36. Muharam., & Saefudin, A. 2016. Pengaruh berbagai pembenah tanah terhadap pertumbuhan dan populasi tanaman padi sawah (*Oryza sativa*) varietas Dendang di tanah salin sawah bukaan baru. *Jurnal Agrotek Indonesia,* 1(2), 141-150.
37. Mulyani, A., Mulyanto, B., Barus, B., Panuju, D. R., & Husnain. 2022. Geospatial Analysis of Abandoned Lands Based on Agroecosystems: The Distribution and Land Suitability for Agricultural Land Development in Indonesia. *Land*, *11*(11), 1-19.
38. Noviwiyanah, D., & Yudhistira, M. H. (2024). Pengaruh Luas Lahan Sawah Terhadap Produksi dan Konsumsi Pangan Di Indonesia. *Jurnal Ekonomi Pertanian dan Agribisnis*, *8*(3), 874-884.
39. Otitoloju, K. (2014). Growth, yield and seed nutritional composition of groundnut (*Arachis hypogaea* LINN) under elevated level of soil salinity. *Molecular Soil Biology*, *5*(5).
40. Plaut, Z., Meinzer, F. C., & Federman, E. 2000. Leaf development, transpiration and ion uptake and distribution in Sugarcane cultivars grown under salinity. *Plant Soil*, 218, 59–69.
41. Purwaningrahayu, R. D., Taufiq, A. 2018. Pemulsaan dan ameliorasi tanah salin untuk pertumbuhan dan hasil kedelai. *Jurnal Agronomi Indonesia*, 46(2), 182-188.
42. Putri, P. H., Susanto, G. W. A., & Taufiq, A. 2017. Evaluasi ketahanan sumber daya genetik kedelai terhadap cekaman salinitas. *Jurnal Penelitian Pertanian Tanaman Pangan* 1(3): 233-242.
43. Qiu, Y., Wang, X., Xie, Z., and Wang, Y. 2020. Effects of gravel-sand mulch on the runoff, erosion, and nutrient losses in the Loess Plateau of north-western China under simulated rainfall. *Soil Water Res*, 16, 22–28.
44. Rao, V. P., Sengar, R. S., Singh, S., & Sharma, V. 2015. Molecular and metabolic perspectives of sugarcane under salinity stress pressure. *Progress. Agric*, 15, 77–84.
45. Robin, A. H. K., Matthew, C., Uddin, M. J., & Bayazid, K. N. 2016. Salinity induced reduction in root surface area and changes in major root and shoot traits at the phytomer level in wheat. *J. Exp. Bot*, 67, 3719–3729.
46. Sabir, M. S., Khattak, M. K., Haq, I. U., Hanif, M., & Amjad, S. 2021. Impact of different levels of bulk densities combination on yield and yield components of wheat (*Triticum aestivum* l.). *Pak. J. Agri., Agril. Engg., Vet. Sci*, 37(2), 79-86.
47. Sanga, D. L., Mwamahonje, A. S., & Mahinda, A. J. 2024. Soil salinization under irrigated farming: A threat to sustainable food security and environment in semi-arid tropics. Journal of Agricultural Science and Practice, 9(3), 32-47.
48. Setiawan, T. (2020). Proses hidrogeokimia pengontrol salinitas air tanah tidak tertekan di utara Cekungan Air Tanah Jakarta. *Jurnal Lingkungan dan Bencana Geologi*, 5(1), 1–12.
49. Shankar, V., & Evelin, H. 2019. Strategies for reclamation of saline soils. In: Microorganisms in saline environments: Strategies and functions, Springer, Cham. Pp. 439-449.
50. Song, Y., Sun, J., Cai, M., Li, J., Bi, M., & Gao, M. 2025. Effects of management of plastic and straw mulching management on crop yield and soil salinity in saline-alkaline soils of China: A meta-analysis. *Agricultural Water Management*, *308*, 1-12.
51. Stavi, I., Thevs, N., & Priori, S. 2021. Soil salinity and sodicity in drylands: A review of causes, effects, monitoring, and restoration measures. *Frontiers in Environmental Science*, *9*, 712831, 1-16.
52. Sui, H., Chen, D., Yan, J., Li, B., Li, W., & Cui, B. (2022). Soil salinity estimation over coastal wetlands based on random forest algorithm and hydrological connectivity metric. *Frontiers in Marine Science*, *9*, 895172, 1-15.
53. Sukarman., Mulyani, A., & Purwanto, S. 2018. Modifikasi metode evaluasi kesesuaian lahan berorientasi perubahan iklim. *Jurnal Sumberdaya Lahan*, 12(1), 1-11.
54. Wang, X., Yang, J., Yao, R., Xie, W., & Zhang, X. 2022. Manure plus plastic film mulch reduces soil salinity and improves Barley-Maize growth and yield in newly reclaimed coastal land, Eastern China. *Water*, *14*(19), 1-14.
55. Wulan, T. R., Ambarwulan, W., Siswanti, E., & Maulana, E. 2016. Variasi kondisi air tanah sebagian pesisir kabupaten rembang kaitannya dengan bentuk lahan. Prosiding Seminar Nasional Kelautan. Universitas Trunojoyo Madura, 173-179.

56. Xie, W., Yang, J., Yao, R., & Wang, X. 2021. Spatial and temporal variability of soil salinity in the yangtze river estuary using electromagnetic induction. *Remote Sens*, 13(1875), 1-16.
57. Xu, R. kou, Zhao, A. zhen, Yuan, J. Hua., & Jiang, J., 2012. pH buffering capacity of acid soils from tropical and subtropical regions of China as influenced by incorporation of crop straw biochars. *J. Soils Sediments,* 12, 494–502.
58. Yildiz, M., Poyraz, İ ., Çavdar, A., Özgen, Y., & Beyaz, R. 2020. Plant responses to salt stress. Plant Breed. Curr. Future Views.
59. Yu, Y. Y., Turner, N. C., Gong, Y. H., Li, F. M., Fang, C., Ge, L. J., & Ye, J. S. 2018. Benefits and limitations to straw-and plastic-film mulch on maize yield and water use efficiency: A meta-analysis across hydrothermal gradients. *European Journal of Agronomy*, *99*, 138-147.
60. Zhang, M., Dong, B., Qiao, Y., Yang, H., Wang, Y., & Liu, M. 2018. Effects of sub-soil plastic film mulch on soil water and salt content and water utilization by winter wheat under different soil salinities. *Field Crops Research*, *225*, 130-140.
61. Zhang, S., Zhu, Q., de Vries, W., Ros, G. H., Chen, X., Muneer, M. A., ... & Wu, L. (2023). Effects of soil amendments on soil acidity and crop yields in acidic soils: A world-wide meta-analysis. *Journal of Environmental Management*, *345*, 118531, 1-12.
62. Zhao, H., Wang, R. Y., Ma, B. L., Xiong, Y. C., Qiang, S. C., Wang, C. L., ... & Li, F. M. 2014. Ridge-furrow with full plastic film mulching improves water use efficiency and tuber yields of potato in a semiarid rainfed ecosystem. *Field Crops Research*, *161*, 137-148.
63. Zorb, C., Geilfus, C. M., & Dietz, K. J. 2018. Salinity and crop yield. *Plant Biol,* 21, 31–38.