

SPECIAL ISSUE ARTICLE

Towards sustainable agriculture for the salt-affected soil

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Abstract

Salt stress is a major problem happening in almost all the world, affecting soil metabolism and acting further negatively soil fertility and soil quality, causing land degradation and low ecosystem service functions and ecosystem productivity. In marshy area as one type of important marginal land resources, salt is also the main barrier to be improved and the driving force to make vegetation succeed. This commentary briefly reviews the main advance focusing on salt-affected soil and introduced the publications in this Special Issue: Salt Soil Improvement and Efficient Development in *Land Degradation & Development* 29, 2018, to promote global cooperation for studying salt-affecting soil quality, land degradation, and eco-restoration.

KEYWORDS

halophytes, improvement, land degradation, salt-affected soil, soil quality

1 | INTRODUCTION

Under the pressure of global climate change and anthropogenic activity, salinization has been a worldwide issue not only severely reducing soil quality and crop productivity but also gradually reducing the area of cultivated land (Bhaduri, Saha, Desai, & Meena, 2016; Cao, Li, Liu, Kong, & Tran, 2018). Currently, more than one third of the world's arable land is subjected to soil quality, and land degradation due to salt stress and agricultural yield has greatly decreased (Fan et al., 2012; Gao et al., 2018; Li et al., 2014; Tilman, Balzer, Hill, & Belfort, 2011). Additionally, the salt-affected area is increasing at a rate of 10% yearly because of high evaporation, low rainfall, inadequate irrigation, and other irrational anthropogenic activity (Himabindu et al., 2016; Liu et al., 2017; Mose et al., 2018). By 2050, the salinized area will exceed 50% of global arable land (Liu et al., 2017; Mao, Kang, et al., 2016; Mao, Zhang, et al., 2016; Sun et al., 2018). So breeding salt-tolerant crops is vital to feed the increasing population (Yamaguchi & Blumwald, 2005). Now, genetic engineering with salt-tolerant genes especially from halophytes is selected as the better strategy to raise crop salt resistance (Himabindu et al., 2016; Mishra & Tanna, 2017; Nikalje, Srivastava, Pandey, & Suprasanna, 2018; Qi et al., 2018; Tang, Mu, Shao, Wang, & Brestic, 2014).

Towards sustainable salt-affected soil agriculture, two ways must be selected: One is from plants themselves; the other is from the salt-affected soil itself. Halophytes surviving in saline environment have developed into a complex strategy to counteract the osmotic stress, ionic toxicity, and oxidative stress induced by salinity. Halophytes growth can improve the salt-affected soil environment, especially the rhizosphere by absorbing salt, increasing microbe's biodiversity and soil fertility and further agricultural productivity. For example, planting Jerusalem artichoke reduced the salt content of soils characterized by high and moderate salinity and also declined the soil pH to a more neutral value and improved saline-alkali soil by enriching bacterial communities, enhancing phosphatase and invertase activities, decreasing soil salinity, optimizing soil structure, and transforming the soil to loam suitable for cultivation (Long, Liu, Shao, Shao, & Liu, 2016; Wang, Tang, & Shao, 2015). Partial halophytes are crop plants including industrial crop plants and medicinal plants (Cao et al., 2018; Jesus, Danko, Fiúza, & Borges, 2015; Kemo, Philip, William, Shen, & Shi, 2017; Liesje, John, & Jasper, 2016; Meier, Finzi, & Phillips, 2017; Mishra & Tanna, 2017; Nicole & Harro, 2016; Nikalje et al., 2018; Qi et al., 2018). Salt-tolerant mechanisms by halophytes include accumulating inorganic ions and organic solutes for osmotic regulation, keeping ion in balance by reducing Na^+ intake, and increasing Na^+ efflux as well as cellular or tissue compartmentalization, detoxification of reactive oxygen species (ROS) by antioxidant systems (Tom, Guiomar, & Paula, 2018). Among these strategies, accumulating proline, glycinebetaine, polyphenols, and soluble sugar is a universal defense mechanism in halophytes. For instance, proline is the most widely-accumulating solute in many plant species. In addition to functioning as an osmoprotectant, it can also quench ROS, stabilize the cellular structure, supply energy, and act as a signal to activate stress responses. Therefore, proline-overproduction synthesis genes are a good way to enhance

plant stress resistance. Our series of studies has shown that this way is applicable (Himabindu et al., 2016; Wang et al., 2015; Xu et al., 2016; Yan et al., 2013).

The other way is to directly improve the salt-affected soil environment for its adapting to plant survival, further planting and conducting eco-restoration. Currently, main remediation methods include physical, chemical, and biological techniques. Previous study concentrated on applying chemicals such as gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), calcite (CaCO_3), and calcium chloride (CaCl_2) providing Ca^{2+} and substituting for Na^+ at the exchange site (Srivastava, Gupta, Shikha, & Tewari, 2016). However, salt-affected soils generally display poor structural stability due to low organic matter in addition to higher salt content. A better method is to apply organic amendments to raise organic matter amount of the salt-affected soil (Montiel-Rozas, Panettieri, Madejón, & Madejón, 2016; Oo, Iwai, & Saenjan, 2015; Reed, Chadwick, Hill, & Jones, 2017; Veneklaas et al., 2012). Different types of organic amendments such as green manures, farmyard and poultry manures, compost, food-processing wastes, and biochar have been applied to soils for enhancing soil quality (Bhaduri et al., 2016; Liu et al., 2017; Xu, Zhang, Shao, & Sun, 2018; Yang, Bian, Tang, Zhou, & Li, 2018). Among these, green manure is a promising way with long-term effects and low cost (Bai et al., 2017; Bai, Xu, et al., 2018; Bai, Yan, et al., 2018; Bai, Zou, et al., 2018; Li et al., 2014; Maltas, Kebli, Oberholzer, Weisskopf, & Sinaj, 2018; Meier et al., 2017; Xu et al., 2018; Yang et al., 2018).

As population increases and urbanization accelerates in most countries, arable land is gradually decreasing. This case is especial for China (Shao, Cui, & Bai, 2012; Shao, Chen, & Marian, 2015; Shao, Lu, Xu, & Brestic, 2017). Modern agriculture is facing a serious challenge beyond the coming decades. Soil is the most important resources for our survival. How to increase arable land is the key to sustainable agriculture development. China has extensive marshy land resources that can be improved for arable resources, which will also be good reference for enlarging global arable land (Figure 1). Extensive investigations have been conducted in China for the past 30 years,

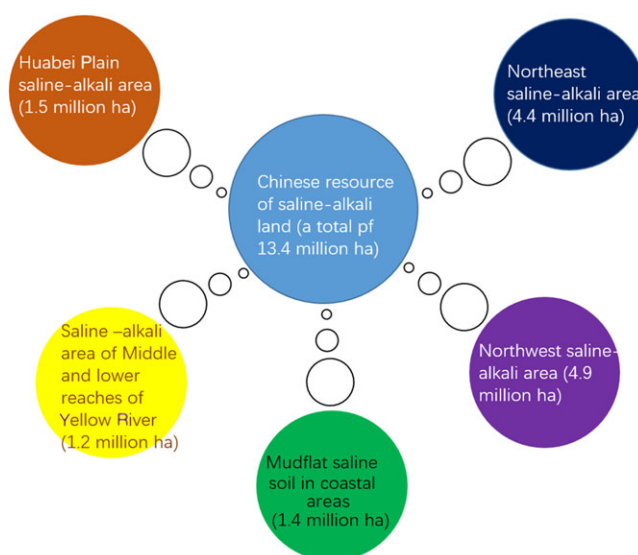


FIGURE 1 Distribution of Chinese saline-alkali land [Colour figure can be viewed at wileyonlinelibrary.com]

and significant progress has been made. For concluding these advances as an example of salt soil improvement and efficient development and demonstration and in the invitation of *Land Degradation & Development*, a journal with focus on land degradation and development, we organized this topic.

2 | REPRESENTATIVE ADVANCES

The Section (topic or issue) of Salt Soil Improvement and Efficient Development in *Land Degradation and Development* 29, 2018, has concentrated on mechanisms of salt-soil degradation (biological, physical, chemical, and human activity), nutrient recycling for salt-soil and enhancing salt-soil quality, salt-soil improvement, demonstration and related measures, the scale of salt-soil degradation and monitoring, salt-soil-plant interactions from ecology, physiology, and biochemistry to molecular biology, evaluation parameters for salt-resistant plant species for higher productivity, mitigation and control of salt-soil degradation and pollution protection, remedial practices to rehabilitate or restore degraded salt-soil, adapting mechanisms for salt-soil plants (crops) and high-efficient utilization and sustainable salt-soil agriculture and fine management. We would introduce main aspects by concrete examples as below.

Planting bean plants can increase soil fertility by fixing N (Cao et al., 2018; Mose et al., 2018). Abdel Latef, Srivastava, El-sadek, Kordrostami, and Lam-Son Phan Tran (2018) applied titanium dioxide nanoparticles to enhance tolerance of broad bean plants under saline soil, obtaining good effects and providing new ideas to improve salt-affected soil in combination with bean planting. Ning, Kan, Shao, and Yu (2018) investigated transcriptional responses to salt stress in salt-tolerant and salt-sensitive soybean (*Glycine max* [L.] Merr.) seedlings and got two important salt-tolerant genes (GmNHX1 and GmNcl1), providing potential base for biotechnologically breed soybean to meet salt-resistant planting. Nikalje, Nikam, and Suprasanna (2017), Nikalje et al. (2018), and Qi et al. (2018) systemically reviewed halophytes selection, related mechanism, utilization, and added value from the angle of physiology, biochemistry, molecular biology, and biotechnology, providing insights into constructing sustainable mudflat salt-affected agricultural ecosystem with high efficiency.

Mudflats along the eastern coast of China can be important alternative land sources for agricultural purpose after improvement for increasing soil fertility and decreasing salt (Ganjegunte, Ulery, Niu, & Wu, 2018; Long et al., 2016). Municipal sewage sludge abundant in organic matter and other nutrients available to plants has the potential use in mudflat as amendment and original fertilizers. Bai, Xue, et al. (2018) and Bai, Yan, et al. (2018) discussed the current status of mudflat-soil amendment using sewage sludge basing on the study of different parts in Jiangsu Province, China, for many years, confirming that sewage sludge application could elevate soil organic matter content and improve soil physicochemical properties subsequently due to raising soil porosity, available nitrogen and phosphorus, and the decrease in bulk density, salinity, and pH in the salt-soil. It is a general fact that the viability to use sewage sludge as organic amendment is conditioning with its content of heavy metals or other contaminants, and both of them strongly link with

the origin of sewage sludge: industrial or residential cities. Bai, Zou, et al. (2018) also responded to these related environmental issues for sustainably applying sewage sludge under the China's State Standard for Agricultural Application of Sewage Sludge (GB/T 24600-2009). In the case of alkaline soils, the potential immobilization of heavy metals could be treated with green manures in combination with biochar (Kripal, 2016; Luo et al., 2018; Srivastava et al., 2016). Luo et al. (2018) examined the maize and grass vegetation systems in reclaiming saline-sodic soils in the Songnen Plain of northeast China, providing an efficient way to copy with the saline-sodic soils. Lu et al. (2018) analyzed periphyton potential roles for salt and nutrient management in degraded mudflats from coastal reclamation, enriching mudflat ecology. Liu et al. (2018) applied remote sensing technology for the three-dimensional mapping of soil salinity by taking Laizhou Bay, China, as an example, providing an efficient way to monitor salt dynamics on a larger scale. Gao et al. (2018) first time analyzed the linkage among land use, streamflow-sediment fluxes, and land degradation changes in the Yellow River Delta across more than 30 years, providing comprehensive insights into land quality and land degradation dynamics. Qu et al. (2018) investigated forms and distribution of soil P in newly formed coastal wetland in the Yellow River Delta estuary, providing important reference for establishing the High-efficient Eco-agricultural Demonstration Zone of China. Soil quality is the important parameter to represent soil degradation and land ecosystem health status. It is insufficient to reflect actual soil quality only based on soil fertility or heavy metal pollution assessment (Kripal, 2016; Liu et al., 2017). Wang et al. (2018) constructed a comprehensive assessment of soil quality for different wetlands in a Chinese delta. The comprehensive assessment set was performed to combine soil fertility and heavy metal contamination together, based on 13 soil physical, chemical, and biochemical indicators and six heavy metals, firstly linking soil pollution parameters with soil quality and opening a new way for comprehensively evaluating land degradation status.

3 | PERSPECTIVES

The topic (section or issue) Salt Soil Improvement and Efficient Development ranging from August 2016 to May 2018 has concluded with success. The topic has attracted more than 300 authors from 19 countries of the world, and they kindly submitted total 63 manuscripts to the topic. Finally, 19 submissions have been accepted for publication after the editorial and peer-review process, which can mainly reflect the current status of salt-affected soil area.

Soil salt ion exchange and property of organic matter and plant growth and development, further influencing physical, chemical, and biological process in the soil environment, and acting on negative effects on soil property and soil quality, causing land degradation (Deinlein et al., 2014; Flowers, Galal, & Bromham, 2010; Munns & Tester, 2008). Improving salt-affected soil and scientific development with efficiency is a worldwide problem, involving in many disciplines (Jesus et al., 2015; Rozema & Flowers, 2008). So understanding the soil-plant interacting mechanism is also quite important, especially around rhizosphere, where crosstalk between soil and plants occurs.

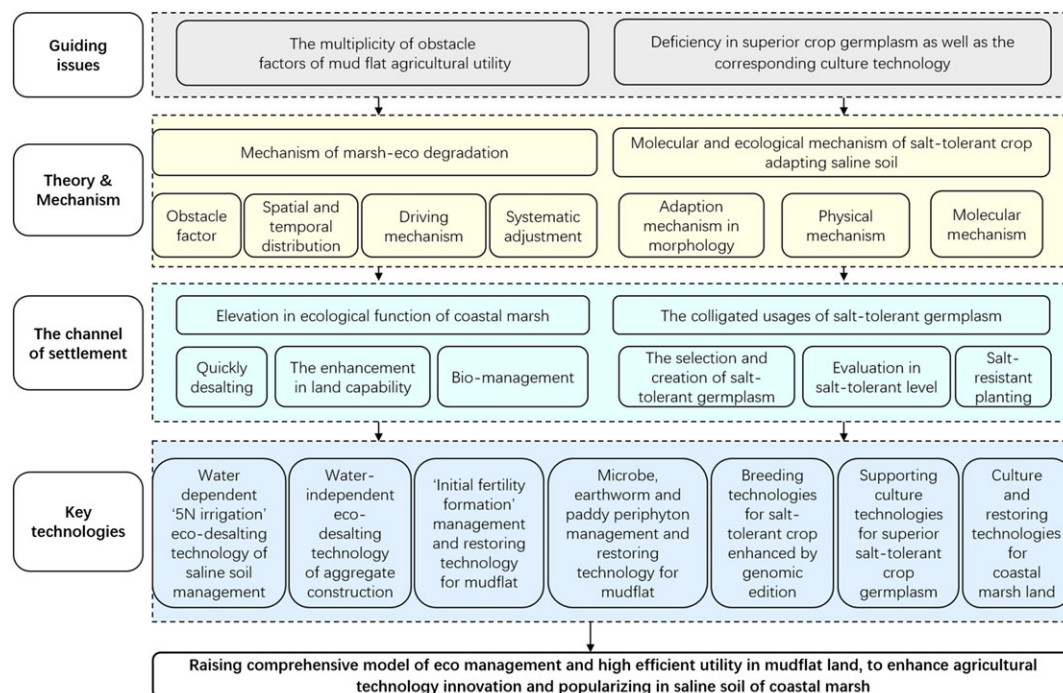


FIGURE 2 The framework for improving and developing coastal salt-affected soil [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

Currently, more combined methodology has been developed to solve the issue (Apse, Aharon, Snedden, & Blumwald, 1999; Kemo et al., 2017; Liesje et al., 2016; Lu et al., 2018a,b; Meier et al., 2017; Miao, Yang, Chen, & Gao, 2012; Munns & Gilliam, 2015; Park, Kim, & Yun, 2016; Shao, 2014, 2017). We have outlined the framework to improve and develop coastal salt-affected soil for reference, which will be the main tendency in the field (Figure 2).

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CONFLICT OF INTEREST

The authors declare no competing interest.

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