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Evolution of Traditional Chinese "Salt-Leaching and Alkali-Washing" Technology and Strategies for Improving Productive Coastal Saline-Alkali Land Landscapes – A Case Study of Cixi City

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Abstract

"Salt-leaching and alkali-washing" is a traditional Chinese technique for reclaiming saline-alkali land, widely used in China's eastern coastal regions. This technique uses irrigation and drainage to reduce soil salinity and alkalinity, transforming land originally unsuitable for farming into highly productive farmland. In Cixi City, with the establishment of modern agricultural parks represented by Zhengda Agriculture, this traditional technique has been combined with modern technology to develop a new "salt-leaching and alkali-washing" method. This greatly increased the efficiency of saline land improvement, converting large areas of heavily saline-alkali land into arable land with mild salinity and achieving very high economic returns. This paper reviews the development history of "salt-leaching and alkali-washing" from ancient times to the present and examines its current applications, and also analyzes how "salt-leaching and alkali-washing" shapes the landscape and its potential for future landscape transformation.

Keywords: Saline-alkali land, Eastern coastal region, revitalization and utilization, productive landscape, landscape architecture

1. Introduction

This paper aims to explore the historical development of "salt-leaching and alkali-washing" from ancient times to the present, as well as the current application of this technology. "Salt-leaching and alkali-washing" is an important hydraulic method for improving saline-alkali soils – it alters the soil moisture through irrigation, thereby affecting the soil's salt content (Wang, 2022). This technique has a long history, dating back to the era of Da Yu's flood control (around 2000 BCE) (Sun, Yan, & Yin, 2024). Even today, it is still widely used in coastal areas of Zhejiang Province, where it has converted large expanses of highly saline, uncultivable land into high-yield saline farmlands, and on this basis modern agricultural parks have been developed. At present, discussions of "salt-leaching and alkali-washing" are mostly found in agricultural engineering research focusing on technical implementation (Li *et al*., 2012).

In the landscape architecture field, some studies have addressed productive landscapes on coastal saline-alkali land (Wang & Wang, 2017), but there is a lack of research tracing the historical context of "salt-leaching and alkali-washing" and exploring its potential for landscape transformation. From a landscape architecture perspective, this paper examines how "salt-leaching and alkali-washing" shapes the surface landscape during the improvement process, and how it can inform future landscape transformation strategies for coastal saline-alkali lands.

The contribution of this study is to highlight the importance of "salt-leaching and alkali-washing" in improving coastal saline-alkali land landscapes, providing new directions for beautiful countryside construction in the eastern coastal region.

2. Background

Coastal saline-alkali land is an important land type in China, with an extremely broad distribution. China's eastern coastal region contains about 210 million mu of saline-alkali land, representing a huge reserve of agricultural land. Saline-alkali land is a general term for various saline soils and alkali soils and soils with different degrees of salinization and alkalization (Zhang, 2011). By definition, saline-alkali land refers to soil containing soluble salts in high solubility and concentration that inhibit plant growth and destroy original soil nutrients, making it difficult for vegetation to grow. Based on salt content, saline-alkali land can be classified as mildly, moderately, or severely saline-alkali (Li *et al*., 2012).

Modern "salt-leaching and alkali-washing" encompasses specific practices such as flushing salt with fresh water, digging drainage ditches, and introducing water for rice cultivation. These measures effectively reduce the salt content in the soil and have been widely applied with good results in the coastal saline lands of Zhejiang. Current research focuses on how to optimize the "salt-leaching and alkali-washing" technique to reduce the cost of improving saline land and to increase agricultural yield and quality.

Northern Cixi contains vast newly reclaimed coastal tidal flats. The parent material of the soil is fluvial or fluvio-marine deposits; the soil type is coastal saline mud, with deep soil layers and uniform texture. The average salt content from the surface down to 1 m depth is 1‰–4‰, with higher values of 20‰–30‰ and some extreme cases reaching 50‰–90‰. In this area, soil salt content is high, the groundwater table is high, and pH is high; at the same time, wind speeds are high and evaporation is intense (annual sunshine duration of 1,900–2,100 hours), and the groundwater is highly mineralized. These conditions are very unfavorable for saline land improvement, making it extremely difficult (Huang, 2010). Prior to the intervention of Zhengda Agriculture, this area was a wasteland of reeds where crops could hardly grow. In 2011, modern industrial agricultural parks led by Zhengda Agriculture were established here and began improving the saline-alkali land through salt-leaching and alkali-washing. By 2021, the area of high-standard farmland built in the park reached 76.67 km^2, accounting for 74.2% of the park's total area, and efficient water-saving irrigation facilities covered as much as 33.33 km^2(Xu & Jiao, 2022). The area has gradually expanded into a diversified industrial park integrating crop farming, aquaculture, food R&D, food processing, agri-machinery manufacturing, real estate development, eco-tourism, financial services, e-commerce, training, and new energy industries. Turning these saline wastelands into fertile fields was the first step in developing local modern agriculture – and "salt-leaching and alkali-washing" was the foundation of it all.

3. Research Methodology

3.1 Research Focus

3.1.1 Review and Heritage

This research aims to systematically review the evolution of "salt-leaching and alkali-washing" in China's eastern coastal region from ancient times to the present, and to investigate its key technical points, social context, and application patterns in different historical periods. Through comprehensive analysis of historical literature, local chronicles, and field investigations, we elucidate the basic principles, development trajectory, and core role of this traditional technique in saline-alkali land improvement. On this basis, we seek to unearth and carry forward traditional water and soil wisdom to provide theoretical support for its contemporary application.

3.1.2 Modern Application and Innovation

Focusing on the practical case of Cixi City, we examine the contemporary implementation of "salt-leaching and alkali-washing" in coastal saline-alkali land improvement, with an emphasis on how modern water infrastructure (such as multi-tier water networks and "irrigation-drainage integrated road" systems), mechanized operations, and emerging agricultural models (e.g. rice-crab co-culture, water-flooded rice cultivation) are integrated with the traditional technique to form highly efficient, high-value industry models, and to explore possibilities for further innovation and upgrading.

3.1.3 Landscape Shaping and Revitalization

From the perspective of landscape architecture and planning, we analyze the far-reaching impact and unique value of the "salt-leaching and alkali-washing" technique in shaping agricultural landscapes, ecological patterns, and local cultural identity. We explore how landscape design can organically combine agricultural production, ecological restoration, and cultural tourism to achieve multifunctional use and sustainable development of coastal saline-alkali lands. Through landscape revitalization, we aim to enhance local cultural identity and promote the integrated development of rural revitalization and eco-tourism.

3.1.4 Proposed Improvement Strategies and Design Recommendations

Integrating traditional experience, modern practice, and landscape needs, we propose practical strategies for coastal saline-alkali land landscape improvement and revitalization. These strategies balance ecological restoration, water resource management, economic benefits, and local cultural character, and are intended to provide scientific, systematic references and demonstrations for saline-alkali land improvement and landscape creation in other similar regions.

3.2 Research Questions

A. Historical context and technical wisdom:

- *Question 1:* What are the origins and historical development trajectory of the "salt-leaching and alkali-washing" technology in China's eastern coastal region?
- *Question 2:* In different historical periods (e.g., Song, Ming, Qing, Republic of China), how did people in the Cixi area utilize freshwater resources, construct sea dikes, and dig channels to reclaim saline-alkali land? What were the core mechanisms of these measures and the successful water-management wisdom behind them?
- *Question 3:* What are the specific methods of "salt-leaching and alkali-washing" currently employed by Zhengda Agriculture, and how do they differ from the traditional approach?

B. Landscape shaping and cultural heritage:

- *Question 1:* In the coastal saline-alkali land improvement process centered on "salt-leaching and alkali-washing," what impact does this have on the local water network pattern, topography, and the formation of agricultural landscapes?
- *Question 2:* How can traditional water and soil wisdom be inherited and reflected in modern landscape design or landscape architecture through facility layout, landscape narrative, and public participation.

3.3 Research Strategy

For this qualitative study centered on "salt-leaching and alkali-washing," the core is a cross-dimensional analysis of people–land–water–landscape information. We must both comb through literature and historical context to distill traditional experience and obtain contemporary practitioners' insights and current data through interviews and on-site observations. By employing multiple qualitative methods in combination, we can not only depict the complete process of the technique's evolution and landscape interventions but also delve deeper into the value and significance of this traditional wisdom in modern agricultural landscapes and cultural heritage. The research strategy is outlined in Table 1.

Table 1. Research strategy

Part	Research Method	Research Focus	Research Path
P1	Literature Review	Trace the development of "salt-leaching and alkali-washing" from ancient times to present; understand coastal saline land use in different periods and their socio-economic context; explore cross-disciplinary research (landscape, agriculture, environmental science).	1) Collect ancient books, local gazetteers, historical archives to extract ideas on traditional water engineering and land reclamation.2) Search modern academic papers, government reports, design manuals and industry case studies to analyze contemporary saline land improvement models and landscape practices.3) Compare key concepts and technical processes from different studies to form an overall understanding of the research questions.
P2	Archival Research	Understand the past landscape form and land use of saline-alkali areas in Cixi.	1) Consult relevant materials in local archives, museums or libraries to find historical documents related to saline land and water conservancy.
P3	Field Observation & Oral Histories	Gain a systematic understanding of the operational process and current status of "salt-leaching and alkali-washing."	1) Photograph or sketch site plans and cross-sections, marking infrastructure (canals, sluice gates, roads) and vegetation distribution.2) Keep photo and video records and conduct routine or seasonal observations to capture dynamic changes.3) Interview personnel from Zhengda Agriculture to learn site-specific information and operational procedures.

Part	Research Method	Research Focus	Research Path
P4	Visual Analysis & Landscape Narratives	Discover how "salt-leaching and alkali-washing" transforms the surface landscape through imagery and narrative.	1) Collect multi-period aerial images or ground photos to analyze landscape changes (e.g., effects on water system, vegetation, farming methods).2) Interpret landscape imagery (such as sea dikes, former salt field sites, agrarian scenes) from a semiotic or narrative perspective.
P5	Case Study & Comparative Analysis	Conduct in-depth analysis of typical areas (e.g., Cixi's Eleventh and Twelfth Polders) or perform cross-comparison of multiple coastal saline land improvement sites; summarize applicable landscape improvement methods; support more general recommendations or theoretical models.	1) Select one or more typical sample regions and gather detailed data.2) Compare each site's water network system, soil improvement cycle, and landscape engineering strategies.3) Summarize common experiences and divergent factors, analyzing the underlying natural, social, and cultural causes.

4. "Salt-Leaching and Alkali-Washing": Traditional Water and Soil Wisdom

4.1 Definition of Salt-Leaching and Alkali-Washing

"Salt-leaching and alkali-washing" is a key method for reclaiming saline-alkali land, achieved by altering soil moisture through irrigation to influence the soil's salt content. When saline soil is flood-irrigated, the salts dissolve into the water; by then draining out the saline water, soil salinity and alkalinity can be reduced. Salt-leaching and alkali-washing is also known as irrigation leaching or flushing salt with introduced water.

Essentially, salt-leaching and alkali-washing applies the principles of water–salt movement. Earlier scholars summarized the relationship between salt and water as: "salt comes with water, salt goes with water" and "large water expels salt, small water draws salt."

4.2 Origins and Development in the Eastern Coastal Region

China has a long history of managing saline-alkali soils. As early as around 2000 BCE, records describe the use of networks of ditches for drainage and irrigation to improve saline land during the time of Emperor Yu's flood control (Sun, Yan, & Yin, 2024) .The Warring States period text *Lü's Spring and Autumn Annals · On Land* also mentioned using field drainage ditches and flushing to wash salt out of soils, a method that was adopted by later generations (Xian, 1991).

In China's eastern coastal region, documentation of salt-leaching and alkali-washing appeared relatively later. In the Yuan Dynasty, Yuan Huang's *Baodi Agricultural Treatise* described using rainwater to wash salt in the coastal area of Baodi, Tianjin. This method required digging ditches and building dikes or erecting stakes to fend off tidal inflows. Fields were designed higher in the middle and lower on both sides, with small ditches every few tens of *zhang*, medium ditches every few hundred *zhang*, and large ditches every few thousand *zhang*, to facilitate the flow of rainwater and freshwater. The engineering plan for salt washing was carried out in a three-year cycle: in the first year, excavate large canals; in the second year, dig medium ditches connecting to the large canal; in the third year, dig small ditches and field channels connecting to the medium ditches. By flushing with freshwater, saline soil was turned into arable land. Initially, a salt-tolerant aquatic grass (water millet) was planted; once the salt and alkali were largely removed, after three or four years the fields could gradually be converted to rice paddies. This method at the time was referred to as "fostering fresh water and sustaining greenery" (Xian, 1991).

Table 2. Development trajectory of "salt-leaching and alkali-washing" in the eastern coastal region

Period	Historical Record	Key Measures	Region
ca. 2000 BCE	*Yu Gong* (Tribute of Yu)	Drainage ditches for irrigation	Saline-alkali lands of Yellow River basin

Period	Historical Record	Key Measures	Region
Warring States	*Lü's Spring and Autumn*	Dig field ditches; flush salts from soil	Saline-alkali lands of Yellow River basin
Yuan Dynasty	*Baodi Treatise on Agriculture* (Tianjin)	Multi-tier ditch network: build dikes and raised fields; plant water millet first, then rice	Coastal saline land of Baodi, Tianjin
Ming Dynasty	*Expanded Meaning of the Great Learning* (Qiu Jun)	Flush fields with river water; construct sea dikes	Coastal saline land of Fujian, Zhejiang
Qing Dynasty	*(various records)*	Dig networks of ditches; partition fields; grade irrigation channels	Coastal saline land of Tianjin, northern Jiangsu

By the Ming Dynasty, there were already accounts of people in coastal Fujian and Zhejiang reclaiming saline-alkali land through salt-leaching and alkali-washing. Qiu Jun's *Expanded Meaning of the Great Learning* recorded how people in these regions flushed coastal saline soils with river water to turn alkaline soil into arable land. It was concluded that to reclaim land near the sea for farming, one must build dikes to block seawater intrusion and dredge channels to bring in freshwater for irrigation. By the late Ming, this method had been used to convert large areas of saline wasteland into rice paddies (Li, 1981).

In the Qing Dynasty, the eastern coastal region continued to employ freshwater flushing to remove salt. In the Zhanggu area, reclamation efforts further divided the improvement zones: the freshwater irrigation ditches were categorized into different grades with varying widths for each grade. This allowed control of water use and reduced waste of freshwater. Moreover, even larger-scale saline land improvement projects were carried out along the northern coast of Jiangsu.

It can be seen that the salt-leaching and alkali-washing technique first emerged in the central plains region and was later gradually adopted in the eastern coastal areas（Table 2）. Over successive dynasties, the method was continuously refined: an increasing number of factors were considered, practices became more standardized, and the efficiency of improvement steadily increased.

4.3 Origin and Development in Cixi

Cixi is located on the Sanbei Plain by Hangzhou Bay, a typical flat plain formed by marine retreat and sediment deposition, with high soil salinity. Starting in the Tang Dynasty, people in Cixi opened up numerous salt pans along the coast, trading salt for money and grain (Zhang, 2023). During this period, driven by the need for water for daily life, production, and transportation, people utilized tidal creeks and tributaries, excavating canals to draw freshwater from the Yao River, Shanglin Lake and other areas in the south up to the north, forming straight north–south canals ("direct rivers"). These man-made waterways laid the groundwork of water infrastructure required for the future "salt-leaching and alkali-washing" technique.

By the Ming Dynasty, large salt works gradually gave way to cotton fields. During this period, people in Cixi concluded that the three most important engineering works for improving saline-alkali land were: constructing sea dikes, digging river channels ("pu"), and building sluice gates (Zhang, 2023). By building sea dikes, newly reclaimed land could be protected from tidal saltwater intrusion; by digging river channels, ample freshwater could be secured for leaching irrigation to reduce soil salt content; and by constructing sluice gates, backflow of saltwater into the channels with the tides could be prevented. The water infrastructure required for "salt-leaching and alkali-washing" thus became a comprehensive system, and people developed a systematic understanding of the technique.

In the Republican period (early 20th century), people in Cixi gained an even deeper understanding of the salt–water relationship, and they summarized concrete methods for improving saline-alkali land through "salt-leaching and alkali-washing": In the coastal sandy areas with the highest salt content, allow freshwater (e.g. rainwater) to infiltrate the soil and install underground pipes to drain it away, thereby flushing out and dissolving salt and carrying it off the land. During summer rains, trenches about three *chi* (roughly one meter) deep were dug every five *chi* to one *zhang* (≈1.7–3.3 m) across the fields to channel the salt-laden runoff into ditches and out of the land. Then, large volumes of water were repeatedly used to flood and rinse the soil; finally, a shallow layer of water was maintained on the field. After the salt dissolved, it was drained away through percolation—repeating this several times removed the salts. Over time, the growth of wild vegetation helped further lower soil salinity. Subsequently, ditches were dug alongside the newly reclaimed fields, and at the end of winter or beginning of spring a layer of fresh mud rich in organic matter was spread over the fields. This improved soil structure and simultaneously deepened the ditches to facilitate drainage. Alternatively, straw could be directly spread on the ground to reduce evaporation and the rise of salt to the surface; after the straw decayed, it acted as fertilizer to further improve the soil (Zhang, 2023). By this period, the traditional "salt-leaching and alkali-washing" technique had become fully mature.

Table 3 summarizes the utilization methods of saline-alkali land in Cixi during different historical stages.

4.4 Modern Salt-Leaching and Alkali-Washing Process

Modern salt-leaching and alkali-washing is the method used by Zhengda Agriculture to improve saline-alkali land. Before 2010, the average time required to reclaim saline land in China was 3–5 years, athe per-mu rice yield after improvement did not exceed 350 jin. By optimizing salt-leaching and alkali-washing and related measures, the Zhengda Group completed the saline land reclamation project in the Cixi park in only 1 year, with a post-improvement rice yield of 800 jin per mu (~6,000 kg/ha). Currently, Zhengda Agriculture's rice yields in Cixi exceed 1,150 jin/mu (~8,625 kg/ha), reaching medium-to-high yield levels, making it a model for saline land improvementin China (Zhang *et al*., 2021).

Table 3. History of saline-alkali land reclamation and use in Cixi

Period	**Key Measures**	**Land Use**	**Social Background**	**Stage of Technique Development**
Tang–Ming (7th–17th c.)	Construct sea dikes; dig canals	Salt production	Salt and iron were economic lifelines; salt industry was the region's pillar industry.	Origin： initial practice of salt-leaching begins as part of salt production efforts.
Ming–Qing (16th–19th c.)	Build sea dikes; dig river channels (pu); build sluice gates	Cotton and grain farming	Coastal salt pans moved north; population growth led to shortages of livelihood resources; economy shifted gradually from salt to agriculture.	Systemization ： a complete water management system (dikes, channels, sluices) is established for land improvement.
Republic–Post-1949 (20th c.)	Build sea dikes; flush salts with freshwater	Large-scale cotton cultivation	Cotton cultivation gradually became the region's main industry (replacing salt).	Maturation ： traditional technique reaches full maturity, widely applied for agricultural production.

The primary purpose of salt-leaching and alkali-washing is to use fresh water flushing to reduce the salt and alkali content in the soil. The key is to control the amount of fresh water inundation, the duration and frequency of flooding, and to drain promptly to prevent salt from resurfacing. At the same time, one must strive to minimize freshwater consumption while ensuring the effectiveness of improvement.

The core of salt-leaching and alkali-washing operations consists of four major steps: water diversion, leaching, drainage, and planting.

(1) Water Diversion: Water diversion is the first step of salt-leaching and alkali-washing and forms its foundation. The goal is to bring freshwater from inland sources to the vicinity of the farmland. The focus is on ensuring a sufficient supply of freshwater while controlling usage to reduce waste. Therefore, a complete graded system of rivers, ditches, canals, and sluice gates must be constructed.

In Cixi's Eleventh and Twelfth Polder areas, the freshwater used for salt-leaching comes mainly from rivers and reservoirs in the southern hilly regions, such as the Yao River and Duhu Reservoir. Before Zhengda Agriculture's involvement, Cixi already had a network of north-flowing river channels (“pu”) connecting inland freshwaters to the East China Sea, which served as primary

conduits. First, freshwater is directed northward via primary north–south rivers perpendicular to the coast, ensuring water supply. Then, east–west feeder canals connect these primary channels, forming secondary channels encircling the farmland. Sluice gates connect the secondary canals to the primary rivers; when leaching or irrigation is needed, the gates are opened to release water into the secondary network. Beneath the fields, tertiary irrigation ditches are connected to the secondary canals via pumps, which lift fresh water into the fields for the next step of leaching (Figure 1).

(2) Leaching: The second step involves soaking and leaching the fields with fresh water for a number of days. The aim is to dissolve the salts in the soil into the water. This flooding process must be repeated until the soil is suitable for cultivation. The key to leaching is controlling the volume of each water application, the duration of flooding, and the depth of inundation. Based on the area of saline land and its salt content, an overall *required* water volume for leaching is calculated, which is then applied in several rounds; the water volume in each round is called the fractional flushing quota. A reasonable fractional quota significantly affects the effectiveness and cost of leaching. If the quota per round is too small, salts may not fully dissolve and the flushing will not achieve its purpose; if too large, it will waste freshwater.

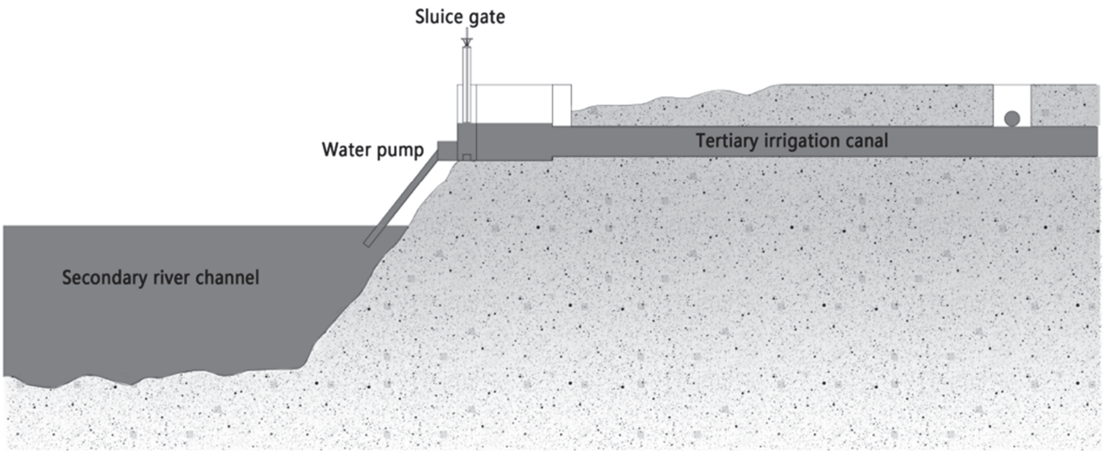
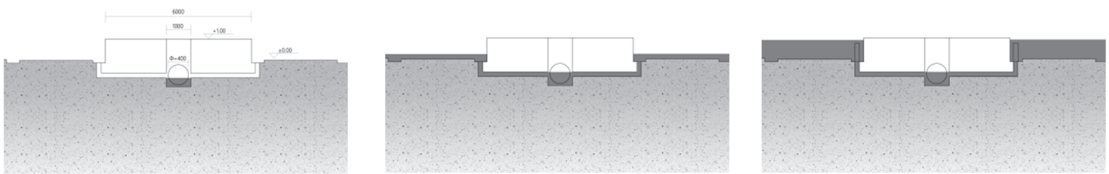


Figure 1. Water diversion stage. Source: illustration by Shiyuan Lou.



Normal Water Level | *Immersion water level without the inserted pipe* | *Immersion water level with the inserted pipe*

Figure 2. Leaching stage. Source: illustration by Shiyuan Lou.

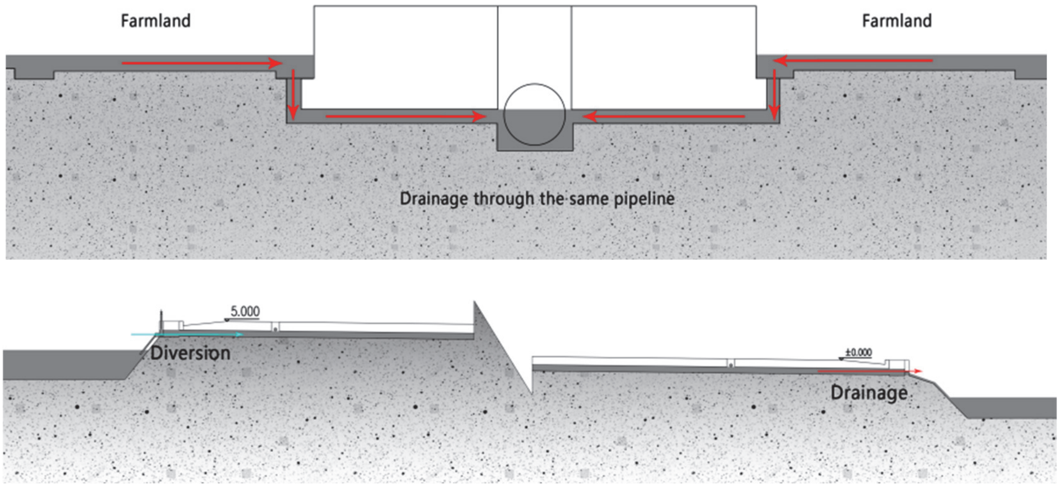


Figure 3. Drainage stage. Source: illustration by Shiyuan Lou

During leaching, fresh water is first introduced into a network of buried "drain tiles" (subsurface perforated pipes) laid beneath the field. These tiles have lateral pipes running east–west every 50 m, connected to the surface for irrigation. When it is necessary to soak the field more deeply to fully dissolve salt, 1 m tall vertical riser pipes can be inserted at the surface outlets of the lateral pipes, thereby raising the inundation water level. Each round of leaching involves flooding the field for 2–3 days, then draining the water and letting the field dry for about one day. Between successive inundations, there is an interval—after one round's water has drained off, some time is allowed before the next flooding. The purpose of these intervals is to increase the time for salts in the soil to dissolve, raise the soil temperature, lower the groundwater level, and improve percolation, thereby enhancing the desalination effect. The length of the interval is not fixed: in areas with lighter-textured, well-drained soils and where groundwater recedes quickly (and sulfate salts predominate), the interval should be as short as possible—ideally, the next leaching begins as soon as the previous water has drained. In areas with a high groundwater table and slow drainage, intervals of 1–3 days may be needed (Figure 2).

(3) Drainage: The third step is timely drainage of the water after leaching; otherwise, salt can resurface (a phenomenon known as salt rebound), undermining the efficacy of salt-leaching. Emphasis is placed on improving drainage efficiency by establishing a well-designed drainage system. The farmland is engineered with a gentle slope (higher in the north, lower in the south) so that gravity can accelerate drainage. At this stage, the inlet sluices and pumps are closed, and the outlet drainage sluices are opened. Once the drainage gate is opened, water flows by gravity into drainage ditches, then into the connected river channels (pu), and ultimately is discharged into the East China Sea.

After the saline water from leaching is drained, the field is typically left to sun-dry for 1–2 days until the water has completely receded, before the next round of leaching. Different soil types require different drying times. Saline soils that are lighter or more permeable will drain and dry more quickly; conversely, heavier-textured or less permeable soils require more time (Figure 3).

(4) Planting: The fourth step is to further reduce soil salinity through planting. After several rounds of leaching, the soil's salt content falls to about 0.3%–0.6%, meaning the land is transformed from severely saline to moderately saline. At this point, rice cultivation can be introduced as a means to continue land improvement while also gaining production. When planting rice, the dry land is converted into paddy fields; similar to the leaching principle, salt in the soil can dissolve into the standing water. After a few seasons of rice cultivation, deep plowing and land leveling can break up the salt-rich surface layer and mix it with the lower-salinity subsoil, thereby reducing surface salt. In 2014, Zhengda Agriculture innovated a water-flooding method of rice cultivation, in which the paddy field is kept inundated with water for extended periods. Using this method, they not only improved the saline soil during the cultivation process but also achieved a yield of 800 jin/mu in the very first season.

Aside from the water-flooded rice method, salt-tolerant green manure and cover crops such as alfalfa and oats can be planted. Their growth and subsequent plowing into the soil increases soil organic matter, improves soil structure, reduces moisture evaporation, and decreases salt accumulation.

When the soil salinity has fallen to about 0.1%–0.3%, i.e. the land is now mildly saline, higher-value crops such as broccoli, watermelon, and rapeseed can be cultivated to improve economic returns. During cropping, practices like rotation and intercropping are used to make full use of limited water resources and to take advantage of different crops' capacities to uptake and utilize salt, thereby mitigating soil salinization.

Furthermore, Zhengda Agriculture has vigorously advanced mechanized farming, dramatically reducing labor costs and enabling one person to manage 300 mu of land. They are continuously incorporating unmanned technologies into agriculture. Currently, by establishing a "smart farm" utilizing IoT, cloud computing, and artificial intelligence, Zhengda Agriculture is retrofitting transplanters, tillers, weeders, harvesters, tractors and other farm machines for unmanned operation. According to Professor Tang Qiyuan of Hunan Agricultural University, "With BeiDou navigation technology, farm machines can operate in the field along planned paths in an orderly fashion" (People's Daily, 2024).

4.5 Comparison of Traditional and Modern Approaches

By separately summarizing traditional and modern practices of salt-leaching and alkali-washing, it is evident that Zhengda Agriculture, building on traditional water and soil wisdom, has streamlined and optimized the steps of salt-leaching and alkali-washing and, through technology, greatly increased the efficiency of the process. Traditional "salt-leaching and alkali-washing," constrained by the technology and productivity of its time, had significant limitations – yet the core principles of the traditional and modern approaches are fundamentally the same. The comparison between traditional and modern salt-soaking methods and alkali-washing methods is presented in Table 4.

5. Agricultural Landscape Shaped by Salt-Leaching and Alkali-Washing

The process of improving saline-alkali land through salt-leaching and alkali-washing reshapes the local water network pattern, topography, and agricultural landscape, creating a distinctive saline farmland landscape.

5.1 Graded Water Network System

Salt-leaching and alkali-washing is inseparable from water management engineering. Driven by the needs of salt-leaching, the Shiyitang and Shiertang areas of Cixi have formed a vast water network connecting inland freshwater lakes and reservoirs to the East China Sea. Cixi's current graded water network system developed from the original "horizontal rivers and vertical *pu*" irrigation–drainage pattern. A *pu* is an inland water channel with sluice gates that connects rivers to the sea, mostly laid out perpendicular to the coastline (hence called "vertical *pu*"); *horizontal rivers* are channels parallel to the sea dikes, running east–west, which also historically served as important transportation routes.

The water network in Cixi has evolved over a long history, dating back at least to the Song Dynasty. Beginning in the Song, people utilized tidal creeks and tributaries and excavated canals to draw freshwater from the Yao River, Shanglin Lake and other southern sources northward, forming a series of straight north–south channels. During the Jiajing period of the Ming Dynasty, several channels were dug through the main Tangka River, forming vertical *pu* channels. From then on, an integrated water network of east–west "horizontal rivers" (with the Tangka River as a main artery) and connecting north–south "vertical pu" channels gradually took shape, providing both irrigation/drainage and transportation functions.

Table 4. Comparison of traditional vs. modern salt-leaching and alkali-washing

Stage	Traditional Approach	Modern Approach	Traditional Limitations	Modern Improvements
Water Diversion	Relied on natural rainfall flushing; manually dug ditches; simple graded ditch system.	Complete graded system of rivers, ditches, canals, and sluices; standardized widths and depths for each channel level.	Low water diversion efficiency; highly dependent on natural conditions.	High diversion efficiency; water volume can be precisely controlled with automated equipment, reducing waste; sufficient and uniform water supply

Stage	Traditional Approach	Modern Approach	Traditional Limitations	Modern Improvements
				with minimal reliance on natural rainfall.
Leaching	Manually dug surface trenches; utilized natural rainfall or nearby river/lake freshwater to soak and flush fields.	Uses installed subsurface drain pipes and an "irrigation–drainage integrated road" system; pumps actively introduce freshwater into fields for targeted soaking and leaching.	Limited scale of leaching; uncertain control over duration, inundation depth, and leaching cycle.	Capable of leaching large areas; flooding duration, depth, and cycle can be precisely controlled.
Drainage	Primarily via open surface drains and a few sluice gates.	Comprehensive drainage system, including buried drainage pipelines, multi-tier drainage ditches, and automated drainage sluice gates.	Drainage heavily influenced by natural factors; low drainage efficiency, prone to salt rebound.	Ensures high-efficiency drainage and prevents salt rebound, securing the improvement results.
Planting	Monoculture of a single salt-tolerant crop; rotated water millet and rice; farming depended mainly on manual labor and draft animals.	Diverse crop rotations; various intercropping and rotation patterns; extensive mechanization and adoption of unmanned (smart) farming technology.	Single cropping pattern, low economic value, high labor intensity and cost.	Diversified cropping systems with higher economic value; high levels of mechanization and automation reduce labor and increase productivity.

In the Republican period (20th century), as the Sanbei Plain underwent large-scale transition from salt production to agriculture, vast cotton fields emerged. Because the northern coastal area had few natural rivers and irrigation was difficult, these cotton fields were ecologically fragile. In addition to constructing sea dikes to keep out saltwater, a complete irrigation and drainage system was necessary. People built a network of connected farm ditches: small ditches drained into large *pu* canals,and the large *pu* ultimately discharged to the ocean. The scale of water system construction during this time far exceeded that of previous eras, forming a human-engineered "straight river system" (Zhang, 2023).

Figure 4. Hierarchical Water Network Landscape: Past vs Present

Source: https://mp.weixin.qq.com/s/Kv-0Qsw-TTYviLTMq-13TQ.

After 1949, salt production was gradually phased out and cotton cultivation became the main industry. However, as reclamation extended toward the sea, the historic "lake–river (pu)" system faced problems of shallow, narrow channels and siltation, and could no longer meet irrigation needs. In response, reservoirs such as Shanglin Lake, Duhu, Changhe, Zhouxiang, and Simen were built or expanded, river channels were dredged, and the characteristic "square field water network" landscape began to appear. The coordinated rehabilitation of the water system ("straight river system") laid the foundation for development in the 21st century (Zhang, 2023).

In 2011, after Zhengda Agriculture established operations, they retained and dredged the existing straight-river system, excavated irrigation and drainage canals encircling the farmland, and added sluice gates and pumping stations between waterways. This created a multi-tier network of rivers, ditches, canals, and sluices for more efficient management of freshwater resources. Today, through standardized construction, the primary irrigation canals around fields are 6 m wide, the smaller feeder canals ~3.5 m wide, and drainage ditches 6 m wide, with depths of about 2–2.5 m. Sluice gates and pumps are installed to control water usage and to prevent backflow of brackish water, thus protecting the soil from salt intrusion.

Over its long evolution, the "horizontal river & vertical *pu*" water network system has been continually improved, and the surface landscape feature of "square-field water networks" has been further reinforced, resulting in today's orderly, multi-tiered graded water network landscape (Zhang, 2023) (Figure 4).

5.2 Irrigation-Drainage Integrated Road System

Beyond large-scale water conservancy works, Zhengda Agriculture also innovated agricultural infrastructure by constructing a new water-saving irrigation project – the "irrigation-drainage integrated road" system.

In a field of about 600 mu, a north–south farm road 6 m in width is laid roughly every 140 m. Beneath each road, a main pipeline for both irrigation and drainage is installed. An inlet sluice and an outlet sluice are set at the two ends of each main pipe, which can be opened or closed to regulate water flow according to leaching or irrigation needs (Figure 5). These pipelines lie about 1 m underground and have a diameter of roughly 1 m. Above them, at 50 m intervals, 1m×1 m inspection wells (about 1 m deep) connect the subsurface pipes to the road surface. Through each inspection well, one can see a pair of irrigation/drainage standpipes (vertical wells) every 50 m, extending from the main pipe up to ground level; these are used for leaching irrigation and drainage.

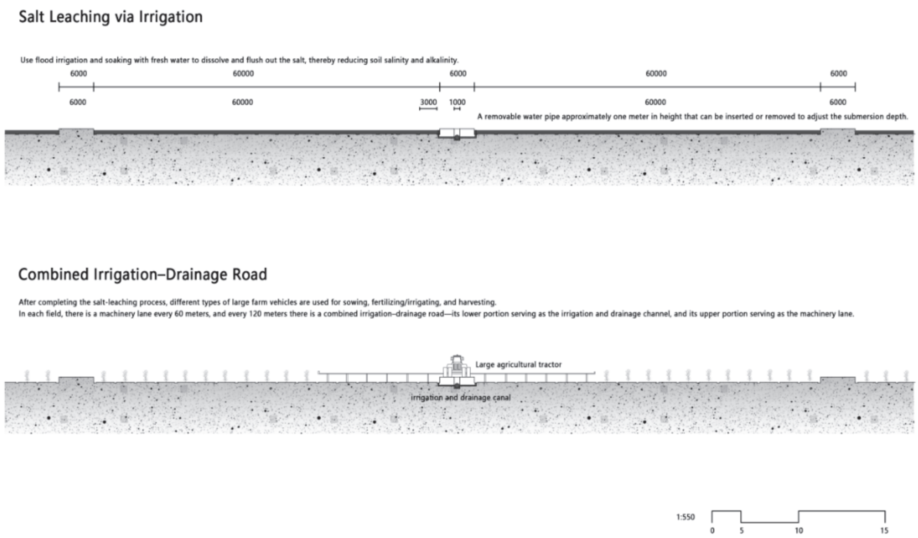


Figure 5. Schematic of the "irrigation-drainage integrated road" system

Source: illustration by Shiyuan Lou.

Figure 6. “Irrigation-Drainage Integrated Road” in practice

Source: photograph by the research team.

Currently, the Zhengda Cixi Modern Agricultural Eco-Park’s water-saving irrigation project is divided into 16 different zones. Five zones, totaling approximately 3,480 mu, are dedicated to rice cultivation – these include traditional integrated irrigation areas, intelligent integrated irrigation areas, and water recycling planting areas. Additionally, more than 10 zones with a total of about 6,520 mu are designated for fruit and vegetable cultivation, including conventional micro-spray irrigation zones, smart micro-spray zones, and greenhouse micro-spray enhancement zones.

The implementation of the “irrigation-drainage integrated road” system allows more effective water conservation and control during salt-leaching, and enables rapid removal of saline water, effectively avoiding salt rebound. Meanwhile, the integrated road system offers advantages such as cost-effectiveness, efficient irrigation, convenient maintenance, and improved efficiency of mechanical farming.

Compared to traditional farmland with separate canals and roads, the integrated system is not only more efficient in operation, but also makes the field landscape more neat and orderly (Figure 6).

5.3 Crop Rotation and Intercropping Landscape

Beginning in the Republican era, cotton cultivation gradually replaced salt production as Cixi’s pillar industry. However, single-crop farming not only failed to ameliorate the saline-alkali soil, it also accelerated the loss of soil fertility and made the soil more compact and saline, thereby affecting cotton yields. In the 1990s, due to national industrial restructuring and pest/disease impacts, cotton acreage in Cixi plummeted; the once “hundred-li cotton fields” (cotton fields stretching for dozens of kilometers) gradually disappeared, replaced by new agricultural landscapes employing crop rotation and intercropping.

Crop rotation can slow the depletion of soil fertility and also help reduce soil salinity. Zhengda Agriculture has selected several relatively salt-tolerant cash crops to incorporate into a rotation schedule. Every October, rapeseed is sown; it is harvested in April–May, then rice is planted and harvested in October of the following year. If rice is not planted, broccoli can be grown from July to December, or a first crop of watermelon from December to April. (Watermelon demands very high soil fertility—once a plot has grown one season of watermelon, it cannot be immediately replanted and a few years are needed for the soil to recover.) By 2014, rice yields in the Zhengda park reached 1,150 jin/mu, and the park produced 8,400 tons of broccoli, accounting for 14% of the city’s total and 1.7% of the national output. This rotation system also creates distinct seasonal crop landscapes and provides more activities to attract visitors. Nowadays, Zhengda Agriculture hosts events such as a watermelon festival and a bayberry festival, inviting large numbers of visitors to stroll along the field ridges, enjoy the scenery, experience fruit picking, and taste the freshest produce (Figure 7).

Since 2016, Zhengda Agriculture has also begun experimenting with an intercropping mode of "rice–crab co-culture." Through three-dimensional farming, river crabs raised in the paddy fields provide manure that serves as organic fertilizer for the rice, enhancing soil fertility; and the presence of crabs helps effectively control weeds and pests in the rice, reducing the need for pesticides.

Rice Field *Rapeseed Field*

Broccoli Field *Watermelon Field*

Figure 7. Crop rotation and rice–crab intercropping landscape.

Source: https://mp.weixin.qq.com/s/YDVPQ69isCl6DKLPKvtlkQ.

6. Improvement Strategies for Productive Saline-Alkali Land Landscapes

The current landscape of the Cixi Modern Agricultural Park is built upon productive reclamation achieved through "salt-leaching and alkali-washing." For the saline farmland landscape improved by "salt-leaching and alkali-washing," the design for its revitalization is considered from two aspects: (1) how the present saline land in Cixi is being improved via "salt-leaching and alkali-washing," and how people can participate in this improvement process; (2) how to enable people to understand and learn about the historical stages that once existed on this land.

For the first aspect, we focus on creating interactive landscapes, utilizing the distinctive characteristics of the four stages of salt-leaching and alkali-washing to design corresponding experiential activities. Because the leaching process must be repeated multiple times and the intensity varies each time, the stages during which people can participate also differ. Therefore, by introducing staged interventions, we can develop appropriate activities and landscape installations for different phases of the leaching process.

For the second aspect, we focus on interpretive landscapes. On the basis of preserving the local cultural context, landscape design can be used to communicate the historical trajectory of saline land use. For example, one could establish a theme park and use landscape narrative techniques to vividly convey historical stories of the land.

6.1 Phased Landscape Intervention

The process of salt-leaching and alkali-washing improvement can be divided into three phases: the initial phase (severely saline-alkali land), the middle phase (moderately saline-alkali land), and the late phase (mildly saline-alkali land). In each phase, the four steps of salt-leaching and alkali-washing play different roles, and people cannot participate equally in all steps. For example, when salinity is extremely high, people cannot safely interact with the landscape immediately after leaching; and the freshwater used in the water diversion stage should not be directly contacted by people to avoid polluting the water and affecting the leaching outcome. Therefore, the design for the improvement process should emphasize observation in some stages and interaction in others, allowing people to engage with different stages of saline land improvement and experience the various steps of salt-leaching and alkali-washing. The interventions at different stages can overlay one another, ultimately forming an agricultural landscape park that can be used well into the future.

6.1.1 Initial Stage (Severely Saline-Alkali Land)

Before improvement, a severely saline-alkali land is often a reed marsh or barren wasteland with hardly any vegetation. In the initial construction phase, prior to carrying out salt-leaching and alkali-washing, water management and land grading projects are necessary. First, the graded water network system must be established to ensure the irrigation and drainage system can function effectively. Second, the terrain must be reshaped—raising the field elevation to prevent salt from rising to the surface via capillary action. During this process, "observation pavilions" and safe routes can be set up within the fields, and lookout points can be built on the sea dike, so that people can observe the early construction process of saline land improvement from a safe distance and gain an initial understanding of the square-field water network landscape.

After the infrastructure is in place, salt-leaching and alkali-washing operations begin to initially reclaim the saline land. In this phase, the steps of water diversion, leaching, and drainage are involved. Freshwater is first channeled into the irrigation canals, then—using the "irrigation-drainage integrated road" system—the fields are flooded for a few days, and finally the saline water is drained away. At this time, aside from the water diversion step, the water involved in the leaching and drainage steps contains high salt concentrations and is not suitable for direct human contact; likewise, the freshwater in the diversion step should not be directly touched by people, to avoid contaminating it and affecting the leaching efficacy. Therefore, during the initial phase of improvement, the design should center on observation. The primary focus can be on the water diversion stage and the supporting graded water network. A tour route could be designed that starts from the water source (e.g. a reservoir) and follows the water flow northward, passing through the system of rivers, ditches, canals, and sluice gates, allowing visitors to learn the operating principles of the graded water network. Through informational signage and guided explanations along the way, visitors can further understand the evolution of the water network system—from the construction of sea dikes, to the "horizontal rivers and vertical pu" pattern, to the "straight river system," and finally to today's graded network—and recognize the origins of the square-field water network landscape.

For the leaching and drainage steps in this phase, an elevated boardwalk along the field ridges with observation points can be constructed, enabling visitors to observe and learn during the leaching and drainage processes. Along the boardwalk, educational panels can explain the causes of saline-alkali soil and the principles of salt-leaching and alkali-washing, allowing people to learn about these concepts in the context of the actual site.

6.1.2 Middle Stage (Moderately Saline-Alkali Land)

In the mid-improvement phase, the salinity of the water after each leaching has gradually decreased. Interactive activities can now be introduced in conjunction with the water diversion, leaching, and drainage steps, with an emphasis on demonstrating the operation of the "irrigation-drainage integrated road" system. This phase focuses on engaging and educational experiences (especially for children), aiming to teach through play and help participants understand the salt-leaching process.

For the water diversion stage, the design can highlight the inlet structures. At the water intake, electric pumps draw fresh water into the underground pipes of the integrated road system. Near some of these pumps, interactive human-powered devices such as an Archimedes screw pump or a seesaw pump can be installed to provide a hands-on appreciation of the water diversion process. Additionally, small spray features can be mounted on the pumps, and a portion of the area can be set aside as a safe water-play zone without affecting the leaching process). (Figure 8)

Archimedes Water-Lifting Device *Small Sprinkler Device*

Figure 8. Interactive water inlet devices (e.g., Archimedes screw pump and mini spray pump).

Source: https://mp.weixin.qq.com/s/wglOhnAXM1I2tw_xc7M-VQ.

hand-operated water-scooping device

Figure 9. Interactive drainage outlet installation (tiered spillway steps).

Source: https://mp.weixin.qq.com/s/wglOhnAXM1I2tw_xc7M-VQ.

During the leaching step, when water covers the fields to a depth of 1–2 m for 1–2 days, a small inflatable boat center can be provided, offering boat rides. When the temporary "water field" is deeply flooded, visitors can paddle boats in the inundated fields, thus taking part—symbolically—in the leaching process.

After a round of leaching is completed, the water needs to be drained. The optimal spot to observe drainage is typically at the drainage sluice on the north side of the fields, where one can watch how water flows through the sluice into the drainage canal. Here as well, interactive installations can increase engagement. For instance, a tiered spillway structure can be installed just below the sluice gate, integrated with stepped seating, so that children can get close to and even touch the cascading water as it flows down (Figure 9).

6.1.3 Late Stage (Mildly Saline-Alkali Land)

In the late improvement phase, continual freshwater flooding is no longer necessary; instead, soil salinity is reduced through planting. Therefore, in this phase the main interactive experience centers on participation in the planting stage.

At the beginning of the planting-based improvement, the water-flooded rice cultivation method is employed so that salt is further leached out by the water in which the rice grows. The key difference of this method compared to ordinary rice farming is that the paddy field is kept flooded for an extended duration. Additionally, a form of integrated farming is implemented by raising crabs in the rice paddies. At harvest time, a “Rice & Crab Festival” can be held: people can take part in cutting rice and catching crabs, and immediately enjoy tasting the fruits of their labor.

Beyond rice, Zhengda Agriculture also rotates other crops such as broccoli, rapeseed, watermelon, and grapes. Similarly, each harvest can be celebrated with related events that combine picking produce, purchasing goods, and tasting food, attracting individual tourists as well as educational tour groups (Figure 10). Accordingly, facilities for hosting such events are needed, including a visitor center, dining areas, marketplaces, as well as supporting infrastructure like parking and public restrooms. Knowledge about the planting-based improvement methods can be disseminated through organized study camps, agricultural lectures, and informative displays.

Figure 10. Watermelon festival event hosted at Zhengda Cixi Agricultural Park.

Source: https://mp.weixin.qq.com/s/plAruLnNKuRz7G74Jyjw6Q.

6.2 Showcasing Different Historical Periods

The saline-alkali land in Cixi took on different characteristics in different historical periods. A challenge for design is how to present the distinctive features of each historical era in the landscape.

There are already theme parks with related concepts that offer reference points. For example, the Nanpu Salt Culture Park in Tangshan, Hebei. The Nanpu Development Zone’s transformation—from a historic sea salt production site to today’s national marine chemical industry base—has always been closely tied to salt. The landscape design team of that park placed sculptures, relief murals, and information walls at important nodes to recreate the salt-making processes of the ancients and to display the developmental history of the Nanpu area (Figure 11).

The historical evolution of saline land use in Cixi can be broadly divided into: the salt-making era, the cotton-planting era, the cotton–rice rotation era, and the modern agricultural park era. Meanwhile, the utilization of saline land is inextricably linked with Cixi’s culture of land reclamation and sea-dike construction, which should be incorporated into the historical narrative as well. Given the wide range of themes and content, a saline land culture theme park could be established.

The park would be organized under the theme “Ever-changing land: from ocean to farmland, the transformation of saline-alkali land,” and structured along a historical timeline, dividing the space into four major sections: Birth of the Saline Land, Zhejiang Salt Capital, Hundred-Li Cotton Fields, and Modern Farmland. The history of sea-dike construction and the development of water conservancy would be woven into each section at relevant key historical points, illustrating how changes in saline land use closely paralleled those developments.

Through a thoughtfully designed circulation route, visitors would traverse these sections in chronological order. Within each section, elements such as sculptures, educational walls, and relief art could be used to showcase the landscape of the past. Each section could also feature its own special activity zone to provide immersive experiences: for instance, in the “Zhejiang Salt Capital” section, visitors might experience traditional salt-making; in the “Hundred-Li Cotton Fields” section, they could try cotton carding and spinning. This would enrich the learning experience with hands-on engagement.

Figure 11. Nanbao Salt Culture Park in Tangshan, Hebei.

Source: https://mp.weixin.qq.com/s/QTJgSjKdAX2hYyNDEXf8rg.

7. Conclusion and Outlook

The productive landscape formed by reclaiming saline-alkali land with the “salt-leaching and alkali-washing” technique not only demonstrates a unique landscape aesthetic potential but also contains deep cultural connotations. At present, research on “salt-leaching and alkali-washing” has mostly focused on technical implementation and improving agricultural productivity, whereas aspects such as landscape formation, cultural heritage, and social participation remain relatively weak. Future research should place greater emphasis on interdisciplinary integration, combining perspectives from landscape architecture, ecology, sociology, and other fields to explore the comprehensive application of “salt-leaching and alkali-washing” in coastal saline-alkali land improvement. At the same time, efforts should be strengthened to excavate and carry forward traditional water and soil wisdom, and, in combination with modern technology, further innovate the techniques and methods for saline land improvement.

In current and future development, the concept of sustainable landscapes requires that in the process of improving saline-alkali land, we focus not only on agricultural production efficiency, but also on the health and stability of the ecosystem. Enhancing the “salt-leaching and alkali-washing” technique to reduce freshwater waste and improve water-use efficiency will be a key point of technological innovation moving forward.

The future improvement and landscape revitalization of coastal saline-alkali lands will require continuous technological innovation, but also, at the conceptual level, a stronger emphasis on the multifaceted integration of ecology, culture, and economy. The experience from Cixi can be extended to many other regions: through comprehensive improvement and diversified utilization strategies, these coastal saline-alkali lands can be transformed into new agricultural landscapes that integrate crop production, ecological restoration, cultural heritage, and tourism. This will provide new impetus for the sustainable development of the eastern coastal region.

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