设计生态学的景观绩效实证研究
——以天津桥园公园盐碱地改善为例

EMPIRICAL RESEARCH ON THE LANDSCAPE PERFORMANCE OF DESIGNED ECOLOGIES THROUGH A FIELD OBSERVATION OF SALINE-ALKALI SOIL IMPROVEMENT IN QIAOYUAN PARK OF TIANJIN

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摘要

快速城市化导致自然生态系统退化，其调节、净化、生产等服务受到严重破坏。景观设计作为当代改善城市环境的重要手段，应当更加重视对景观功能与过程的设计，使公园、绿地等景观成为城市重要的生态服务供给者，而非城市的负担。为此，俞孔坚提出了“设计生态学”概念：它是人工的生态或人工设计的生命（包括人）与自然环境相互作用的系统，是景观设计及规划塑造的生态过程，也是一种跨尺度、跨学科的实证主义研究。本研究以基于此概念设计的天津桥园公园为案例，利用生态学实验等方法，对公园盐碱地改良的景观绩效进行了实证研究。研究证明，桥园人工生态系统实现了设计的预期目标，即经过景观设计的公园坑塘区域土壤pH值明显低于非设计区域，并且不论在坑塘内部微环境还是在坑塘区域整体空间上，都将土壤盐分累积在地势较低的空间，从而达到了显著的排盐排碱效果。其设计模式对类似城市公园和绿地景观的生态设计具有借鉴意义。

关键词
设计生态学；景观生态设计；桥园公园；生态学实验；景观绩效；盐碱地改良

ABSTRACT

The current rapid urbanization leads to a degeneration in natural ecosystems whose regulating, purification, and production services have been seriously damaged. Landscape architecture focusing more on landscape functions and processes in this context is significant to urban environment improvement, by creating more urban parks and green spaces to provide ecological services as benefits rather than cities' burdens. Therefore, Yu Kongjian defined Designed Ecology as a constructed ecosystem or a system of interactions between living creatures (including human beings) and nature by human design, also ecological processes formed by landscape architecture and planning, and an interdisciplinary, cross-scale, and empirical research in a form of landscape. This research examined the landscape performance of saline-alkali soil amelioration in Qiaoyuan Park designed with the Designed Ecology principles by ecological experiments. The results prove that through micro-topography design, the park's constructed ecosystem significantly drains away salt and alkali to the lower areas of the site, both within the pond and across the whole pond system, achieving its design goal. This case study provides models for similar ecological landscape design of urban parks and green spaces.

KEY WORDS
Designed Ecologies; Ecological Design of Landscape; Qiaoyuan Park; Ecological Experiment; Landscape Performance; Saline-Alkali Soil Amelioration

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1 引言

快速城市化导致城市不断蔓延、土地破碎化严重，原始自然生态系统迅速退化，生态系统的调节、净化、生产等服务受到严重破坏[1]；城市公园和绿地的设计形式和风格变得毫无意义，体现了现阶段的景观设计片面追求所谓的美学价值，对自然环境的保护和自然资源的有效利用并不重视。在这一背景下，以“设计生态学”（Designed Ecology）理念为指导的、人工设计建造的“第二自然”应运而生，旨在为城市带来更多生态价值。

“设计生态学”一词最早可追溯到克里斯蒂娜·希尔和俞孔坚于20世纪90年代在哈佛大学设计研究生院的博士研究，其试图在景观设计领域提倡一种新型的自然审美[2]。2011年10月，北京大学建筑与景观设计学院以“设计的生态”为主旨召开了国际论坛，俞孔坚在该会议上首次明确了设计生态学的定义：它是相对于自然的生态而言的，是人工的生态或人工设计的生命（包括人）与自然环境相互作用的系统，亦是景观设计及规划塑造的生态过程。[3]它以传统生态学为基础，是一种跨尺度、跨学科的实证主义研究，将景观作为人工自然的生态介入形式，以改善生态系统服务能力为目标，在降低维护成本的同时塑造多产的景观。与给城市过度装扮的“化妆式”设计不同，设计生态学指导下的景观设计更强调对景观功能的塑造。在当今人类面临诸多环境问题——特别是无序的城市扩张——的情况下，这种景观设计的新方式显得尤为重要。

事实上，类似设计生态学的理念早在美国景观设计之父弗雷德里克·劳·奥姆斯特德的设计中已有体现，他致力于解决那个时代出现的环境污染、洪水等问题。从波士顿后湾公园项目开始，景观设计中开始融入有关自然功能的认知和考量[4]。全世界已有多个国家及地区开展了众多与生态学有关的城市景观项目，如21世纪初期建立的加拿大多伦多当斯维尔公园，成功地将城市废弃地改造成了生态公园；位于美国康涅狄格州郊区的沃特福德约旦湾城市项目将设计实验集成到普通的社会框架和郊区足迹中，通过监测收集到的雨水水质来评估治理非点源污染环境技术的成效[5]；俞孔坚带领的土人设计团队基于设计生态学在国内外多个城市建立了不同尺度的人工生态景观，解决了多重环境问题[6]，例如在中国上海黄浦江沿岸狭长区域建立的后滩湿地公

1 Introduction

The current rapid urbanization leads to an increasing urban sprawl and land fragmentation. Primitive natural ecosystem is in a rapid degeneration, whose regulating, purification, and production services have been seriously damaged[1]. Meanwhile, many design cases of urban park and green spaces simply pursue visual pleasure and tidiness, with less consideration ecological functions eventually becoming burdens on economy and environment.
In this context, the man-made “second nature” has emerged to increase cities’ ecological benefits, guided by the concepts of “Designed Ecologies.”

The use of the term “Designed Ecology” can be traced back to Kristina Hill and Yu Kongjian’s doctoral research in the 1990s at Harvard Graduate School of Design (Harvard GSD). They were trying to promote a new aesthetic of nature in landscape architecture[2]. In October 2011, International Forum of Designed Ecologies was held in the College of Architecture and Landscape of Peking University, when Yu Kongjian defined Designed Ecology for the first time — relative to natural ecosystems, it is a constructed ecosystem or a system of interactions between living creatures (including human beings) and nature by human design, also ecological processes formed by landscape architecture and planning[3]. Based on Ecology, Designed Ecology is developed as an interdisciplinary, cross-scale, and empirical research in a form of landscape. By improving ecosystem services, Designed Ecology is to create productive landscapes with low-cost maintenance.
It emphasizes more on landscape functions rather than forms. Therefore, this new way of landscape architecture responds significantly to contemporary environmental problems, especially the chaos of urban sprawl.

Actually, similar concepts of Designed Ecology were adopted as early as by Frederick Law Olmsted, the father of American landscape architecture. He devoted himself to treatment of environmental pollution and flood issues of his age. Since the Back Bay Fens, natural functions have been considered in landscape architecture[4]. So far, there have been a lot of urban ecological landscape projects across the world. For instance, the Downsview Park in Toronto, Canada built at the beginning of 21st century was renovated from a wasteland to an ecological park; the Waterford Jordan Bay project in the suburb of Connecticut, USA integrated experimental design with ordinary social framework and suburban footprint, which monitored rainwater collection and evaluated the effect of diffuse pollution treatment[5]; China’s Turenscape, guided by Yu Kongjian, has been fundamentally promoting the new form of urban parks and built up ecological landscapes on different scales based on the principles of Designed

园，模拟自然水过滤过程对黄浦江的污水进行层层净化，实现景观用水的自给[7]。

目前，有关设计生态学的研究更多停留在对概念的理论探讨和初步应用阶段，例如《设计生态学：俞孔坚的景观》一书通过俞孔坚及土人设计团队（以北京土人城市规划设计有限公司为主）的22个实践项目和11篇评述文章，对其设计生态学思想进行了全面展示[8]。然而，设计生态学研究与应用的真正关键在于找出场地亟需解决的问题，并于设计之初提出假设，然后通过生态学实验研究的方法进行景观绩效评价，以验证假设并检验设计对场地问题的实际解决效果，现阶段针对这方面的验证研究还相对较少。“景观绩效”最早见于2010年美国景观设计基金会的“景观绩效系列研究计划”（LPS），用于讨论可持续景观设计的价值、量化方法和成功案例等[9]。其评价方法大体分为定性和定量两个方面，包括实验法、历史研究、相关轶事的描述与记录、多变量分析等多种方法[10]，关注每一个具体项目实际绩效的度量。

本研究选取天津桥园公园作为实证研究案例，用生态学实验的方法评价了公园应用设计生态学手段改良盐碱地的景观绩效。研究假设

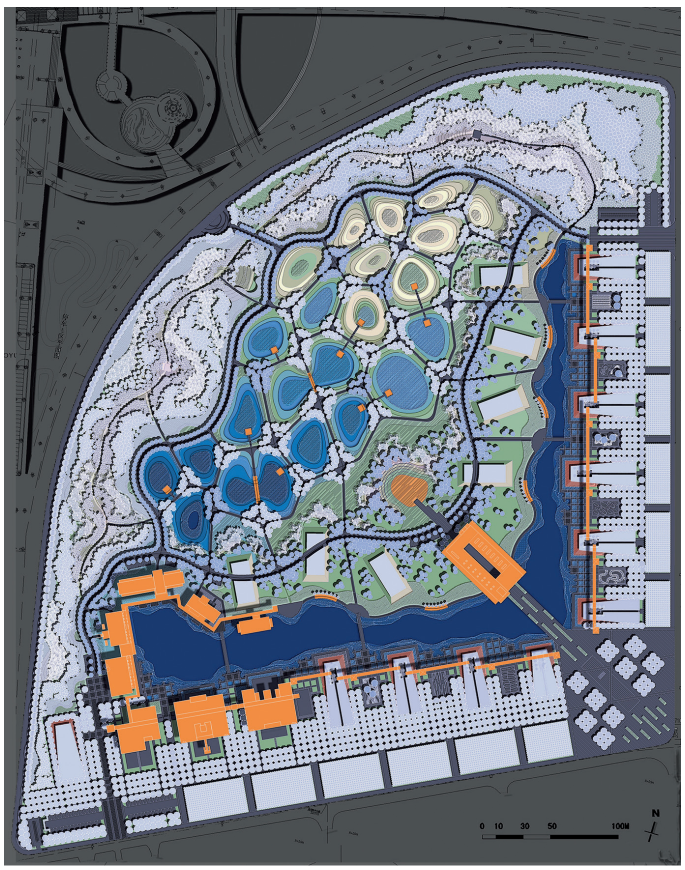
Ecology to address environmental problems in and out of the country[6]. One of their works is the Houtan Park in Shanghai, a strip constructed wetland built along the Huangpu River with natural water filtration and purification to support the water use for its lanscapes[7].

At present, research of Designed Ecology focuses more on theoretical concepts and primary application. The book *Designed Ecologies: The Landscape Architecture of Kongjian Yu* introduces Designed Ecology thoughts with 22 projects by Turenscape team (primarily the Beijing Turenscape) and 11 professional review papers[8]; less research is about whether the designed ecologies achieve their design goals or solve key problems based on landscape performance through ecological experiments, which is the real core of Designed Ecology. Landscape performance assessment was first applied in the Landscape Performance Series (LPS) originally launched by Landscape Architecture Foundation (LAF) in 2010 to explore the value, quantification methods, and empirical experience of sustainable landscape design[9]. Assessment can be done with both qualitative and quantitative methods, including experimentation, historical research, anecdote description, multivariate analysis, and so on[10] focusing on the performance measurement of each program.

This paper takes Qiaoyuan Park in Tianjin as a case study to test designed ecologies based on a field observation of saline-

1. 桥园公园平面图
2. 桥园公园坑塘区域俯视图

1. Site plan of the Qiaoyuan Park
2. Aerial view of ponds in the Qiaoyuan Park



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3. 桥园公园建成前的场地状况
4. 桥园公园内不同设计标高的坑塘

3. The site situation before the design intervention
4. Ponds with different designed elevations

是：运用景观设计的手段确实能有效改善原场地土壤受污染、盐碱化严重等问题。

2 研究区域与研究方法

2.1 桥园公园场地概况

桥园公园位于天津市河东区，总占地面积22hm^2（图1），是天津市内首个人工湿地公园。公园整体为扇形，核心区由众多标高、干湿程度、植物群落各异的坑塘组成，坑塘之间由步道衔接（图2）。

公园原为废弃打靶场，曾垃圾遍地、污水横流、土壤盐碱化严重（图3）。土地污染使土壤无法继续提供自然净化、生产等生态系统服务。2005年，天津市政府启动“桥园生态恢复工程”，希望改变原场地脏乱差的面貌，为城市提供多样化服务。该项目由北京土人城市规划设计有限公司设计，于2006年春开始修建，历时两年正式对公众开放。

公园核心设计理念是“开启自然过程，让自然做功”。通过地形设计，在场地内形成21个设计标高、面积与深度不一的坑塘（图4），场地内部及周边地区雨水可进入坑塘对土壤进行冲刷，将土壤内多余盐分溶解后顺地势排出，再结合芦苇（*Phragmites australis*）、红蓼（*Polygonum orientale*）、菖蒲（*Acorus calamus*）等当地耐盐碱景观植物，达到综合改良公园水和土壤质量的目的。地形与土壤条件各异的坑塘亦提供了多样的栖息地，可形成不同类型的植物群落，营造出形态丰富的水敏性景观，形成色彩斑斓的“适应性调色板”。最终，设计通过修复受损生态系统，将场地改造为一处低维护成本、高生态效益的城市公园。

alkali soil improvement performance. The hypothesis is that the ecological landscape design can significantly mitigate the site’s soil pollution and salinization of Qiaoyuan Park .

2 Research Area and Methods

2.1 Site Introduction

The Qiaoyuan Park is located in the Hedong District, Tianjin with a total area of 22 hm^2 (Fig. 1). It is the first constructed wetland park of the city. The overall shape of the park is like a fan and the core zone is composed of many ponds with different elevations, wetness degrees, and vegetation communities, interconnected with walkways (Fig. 2).

The park was originally occupied as a targeting field with garbage, sewage, and unsightly saline-alkali soil problems (Fig. 3). The purification and production functions of land were severely damaged. In 2005, the city government launched an ecological restoration project to improve the site’s image and provide multiple services for the city. The park was designed by Beijing Turenscape and constructed since the spring of 2006. It opened to the public two years later.

The core design idea of the Qiaoyuan Park was to “turn on the natural process.” It was realized by 21 ponds designed with different elevations, sizes, and depths (Fig. 4) to use rainwater to wash and leach the salt from soil and drain the saline gradually away from the site. Some native salt-tolerant plants, such as *Phragmites australis*, *Polygonum orientale*, and *Acorus calamus* also help the water quality improvement and soil amelioration. Meanwhile, ponds provide habitats for diverse plant communities, building up various water sensitive landscapes. In this way the site converts into a park with high ecological performance and low cost of soil remediation and maintenance.

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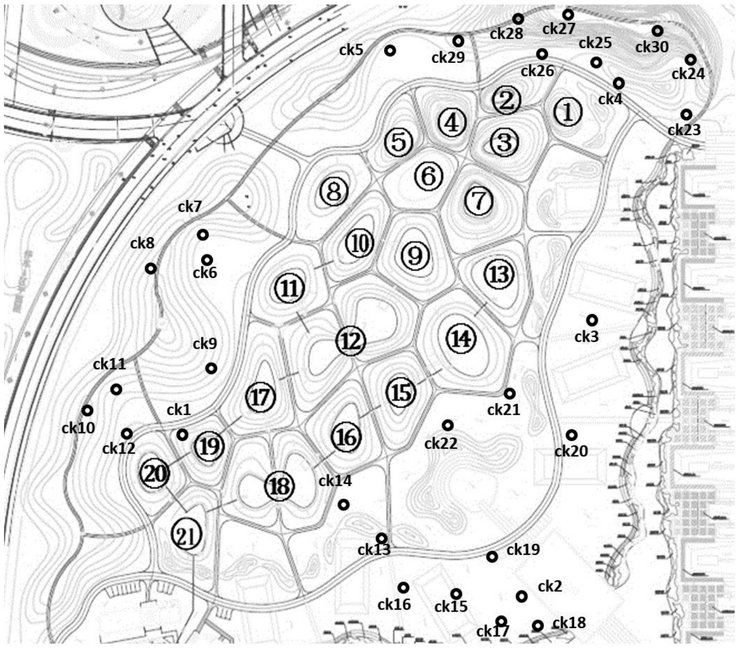

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2.2 研究方法

笔者采集了桥园不同坑塘中的土壤样品，并在坑塘周边的非设计区域设置对照样点，严格按照生态学实验的标准方法，测定了各土样的pH值和电导率，将其作为反映土壤盐碱化程度的指标并分析其变化，以检验桥园公园坑塘设计区域盐碱地恢复的景观生态绩效。

2.2.1 土壤样品采集

因夏季降雨集中且相对较多，雨水对土壤中盐分的冲刷现象较明显，脱盐效果更好，故于2015年7月7、8日进行土壤样品采集。将公园内的21个坑塘以由东北至西南的顺序依次编号（图5），根据坑塘的高程分为高坑塘（高于场地地表高程）和低坑塘（低于场地地表高程），根据内部是否有水分为干坑塘和湿坑塘（表1）。取样时在每个坑塘斜坡的上部和下部各选取一个样点，分别记作“上部采样点”和“下部采样点”（图6），并在均匀分布的不同坡向做三组重复，

表1：桥园公园坑塘分类
Table 1: Classification of ponds in the Qiaoyuan Park

坑塘编号 Number	高程分类 High or low	干湿分类 Dry or wet	备注 Remark
1	高坑塘 High	干坑塘 Dry	顶部为小型广场 Small square on the top
2	高坑塘 High	干坑塘 Dry	
3	高坑塘 High	干坑塘 Dry	
4	高坑塘 High	干坑塘 Dry	人为浇灌为湿坑塘 Irrigated pond
5	高坑塘 High	干坑塘 Dry	人为浇灌为湿坑塘 Irrigated pond
6	高坑塘 High	干坑塘 Dry	
7	高坑塘 High	干坑塘 Dry	
8	高坑塘 High	干坑塘 Dry	
9	高坑塘 High	干坑塘 Dry	
10	低坑塘 Low	干坑塘 Dry	低坑塘但无水 Low pond without water in the bottom
11	低坑塘 Low	湿坑塘 Wet	
12	低坑塘 Low	湿坑塘 Wet	
13	低坑塘 Low	干坑塘 Dry	低坑塘但无水 Low pond without water in the bottom
14	低坑塘 Low	湿坑塘 Wet	
15	低坑塘 Low	湿坑塘 Wet	
16	低坑塘 Low	湿坑塘 Wet	
17	低坑塘 Low	湿坑塘 Wet	
18	低坑塘 Low	湿坑塘 Wet	
19	低坑塘 Low	湿坑塘 Wet	
20	低坑塘 Low	湿坑塘 Wet	
21	低坑塘 Low	湿坑塘 Wet	

5. 桥园公园坑塘编号及全部采样点位置分布图
6. 高、低坑塘实景图及土壤采样点位置示意图

5. Numbers of the ponds and locations of all sampling points
6. Photos and positions of sampling points of the high and low ponds

即每个坑塘取6个斜坡土样。此外，还采集了高坑塘顶部的土壤样品（其中，坑塘1顶部是小型广场，坑塘4和5被人工浇灌成湿坑塘，无法采集）；坑塘10和13由于底部中心处无水也进行了采集（表1），记为“中心采样点”。共采集上部采样点土样66个，下部采样点土样63个，中心采样点土样21个。此外，将坑塘周边非设计区域（如草地）的土样作为对照，共计取样30个（图5）。综上，样本总量为180个。

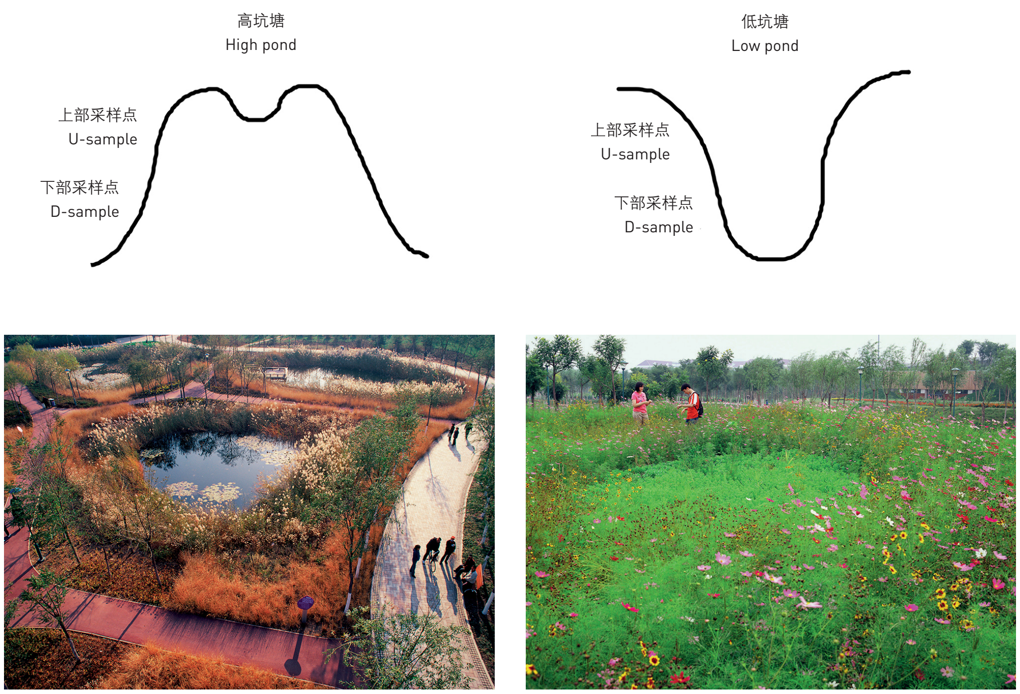
研究利用土钻采集耕层0~20cm的土壤，由此可以保证土样厚度、深浅、宽窄大体一致。每个采样点的土壤采样使用三点混合法，即在同一个地点采集三个土钻的土柱进行混合[11]，以减少取样差异。

2.2.2 指标测定

土壤样品采集完成后，立即带回实验室进行制备、保存和浸提，并对土壤提取液的pH值和电导率进行测定。pH值可表征土壤的碱化程度；电导率与土壤溶液的含盐量呈正相关，可表征土壤的盐渍化程度[11]。酸碱度和含盐量是判别盐碱土壤的两项重要指标，也是影响盐碱地植物生长的障碍性指标[12]。

2.2.3 数据处理

采用R语言和Excel完成数据分析和图像处理。



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2.2 Research Methods

Based on ecological experiment strictly, this research measured and analyzed pH value and electrical conductivity (EC) of collected soil samples in different ponds and control points around ponds in the park to test landscape performance of saline-alkali soil amelioration.

2.2.1 Soil Sample Collection

All soil samples were collected on July 7 and 8, 2015 in the Qiaoyuan Park, since summer days the wash of saline-alkali soil can be observed more clearly due to the intensive rainfalls. 21 designed ponds were numbered from the northeast to the southwest (Fig. 5), and divided into high ponds (designed higher than the ground elevation) and low ponds (designed lower than the ground elevation), as well as dry ponds and wet ponds depending on whether they hold water or not (Table 1). For one pond, two samples were collected respectively in the high and the low parts of one slope of the pond and denoted as U-sample and D-sample (Fig. 6), and such sampling was repeated three times in different directions of the slope side to get 6 soil samples in total. In addition, soil in the top of high ponds was also sampled, except Pond 1 reconstructed as a mini square and irrigated Pond 4 and 5; the bottom of Pond 10 and 13 were also sampled because there was no water. These samples collected from the top and bottom of ponds were denoted as C-samples (Table 1). The total number of soil U-samples, D-samples and C-samples were 66, 63, and 21, respectively. There were 30 soil samples as controls (ck) which were collected from the grassland nearby the ponds (Fig. 5). 180 samples were collected in total.

Soil auger was used to collect topsoil from the ground to 20 cm underground for consistency of soil sample thickness, depth, and width. Sampling follows “three points mixing” method[11] to reduce deviation.

2.2.2 Data Determination

After collecting, soil samples were taken to laboratory immediately for determination of pH value and electrical conductivity. The pH value indicates the alkalinity level of soil; Electrical conductivity is positively correlated with soil salinization level[11]. pH value and salinity are two important indicators for identifying salt-alkaline soil, also indicating the factors which affect growth of salt-alkaline plants[12].

2.2.3 Data Processing

The R programming language and Microsoft Excel were adopted for data and figure processing.

3 结果与分析

3.1 土壤样点pH值测定结果分析

经测定，全部180个采样点的pH值均在7.6~8.8之间。根据目前应用较广的盐碱地国家标准分类（表2），研究区域内土壤样品属于轻度至中度盐碱化。

测定结果和采样点在坑塘内的位置及坑塘属性（包括高低、干湿）有关。由采样点pH值与坑塘不同属性的箱线图和小提琴图（图7）可看出，对照点pH值都相对较高（8.1~8.4），即碱性强。从中位数来看，对坑塘内的不同位置，上部采样点pH值低于对照点，下部采样点低于对照点和上部采样点，中心采样点pH值介于上、下部采样点之间（图7a）。低坑塘pH值的中位数略高于高坑塘（图7b），湿坑塘pH值高于干坑塘（图7c）。

对测定结果进行Wilcoxon秩和检验（表3），发现下部采样点、中心采样点的土壤pH值都极显著低于对照点，上部采样点土壤pH值分别极显著地高于下部采样点和中心采样点；高坑塘的土壤pH值显著地低于对照点，干坑塘极显著地低于对照点和湿坑塘。以均值作为参考依据，对照点pH值分别比下部采样点和中心采样点显著高1.91%和2.09%，比高坑塘和干坑塘高1.10%和1.71%，上部采样点比下部采样点高1.95%。

3.2 土壤样点电导率测定结果分析

土壤坑塘采样点电导率测定结果在0.21~6.26dS/m之间，根据表4的等级划分，研究区域内有4.44%的土壤样品属于轻度盐渍化，均来自坑塘下部采样点；1.67%属于中度盐渍化，均来自10号或13号坑塘的底部中心处。其余采样点电导率均不在盐渍化的范围内，且坑塘下部的土壤样品的电导率值多数偏大。

为增加图形的直观性和可读性，将电导率取以10为底的对数得图8。从中位数来看，坑塘内的上部采样点和中心采样点土壤电导率均低于对

表2：盐碱地国家标准分类[13]
Table 2: National classification of saline-alkali soil[13]

	含盐量 Salinity	出苗率 Emergence rate	pH值 pH value
重度盐碱地 Severe	≥ 6‰	≤ 50%	≥9.5
中度盐碱地 Moderate	3‰~6‰	50%~70%	8.5~9.5
轻度盐碱地 Mild	≤3‰	70%~80%	7.1~8.5

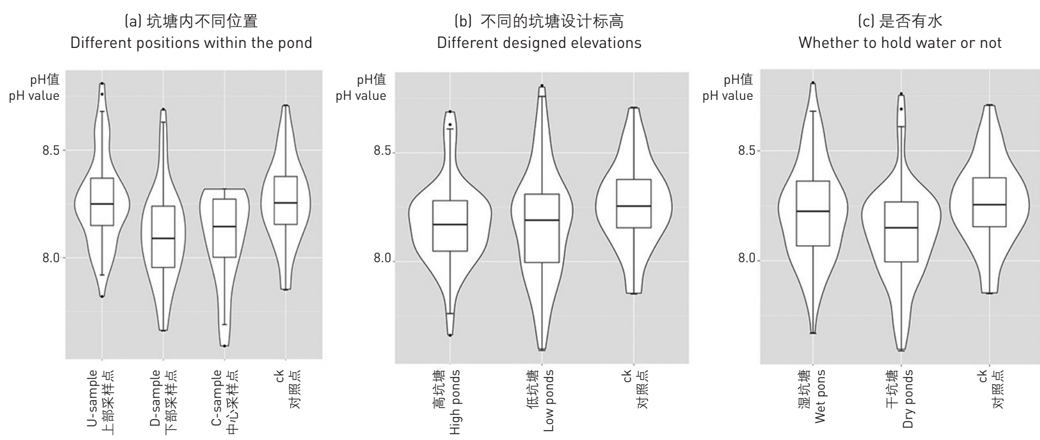
3 Results and Analyses

3.1 pH Value Analyses

Determination results show that the pH values of all soil samples varied between 7.6 and 8.8. According to the widely used national classification of saline-alkali soil (Table 2), the soil samples in the study area indicate a mild or moderate salinization.

The results show a correlation with pond properties of designed elevations and whether to hold water. In boxplot and violin plot figures (Fig. 7), pH values of control points are relatively high (between 8.1 and 8.4). The median pH of U-samples is lower than control points', and D-samples' is lower than U-samples' and control points'. The median pH of C-samples is between D-samples' and U-samples' (Fig. 7a). Median pH of low ponds is a little higher than that of high ponds (Fig. 7b), and wet ponds' is higher than dry ponds' (Fig. 7c).

Wilcoxon rank sum test (Table 3) shows that the pH values of D-samples and C-samples are extremely significantly lower than control points'. U-samples' are extremely significantly higher than D-samples' and C-samples'. The pH value of soil samples collected from high ponds is extremely significantly lower than



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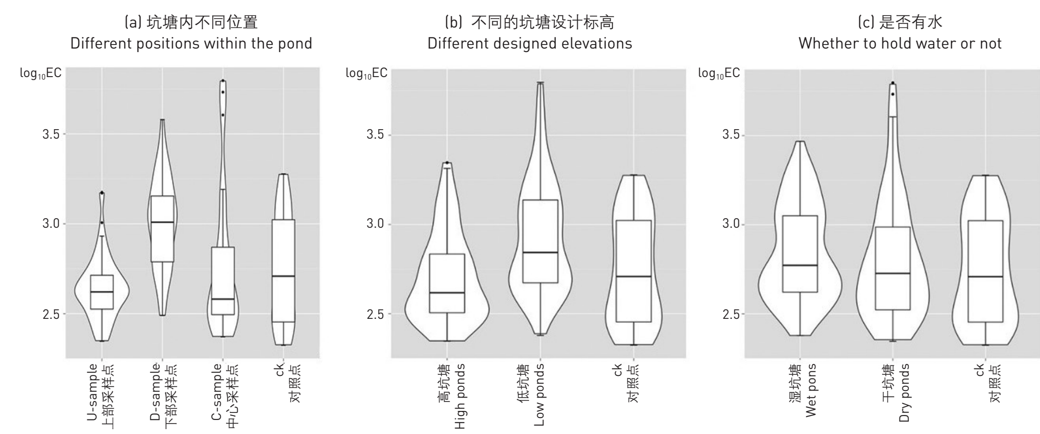

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7. 按坑塘不同属性呈现的土壤样品pH值测定结果
8. 按坑塘不同属性呈现的土壤样品电导率测定结果

7. Boxplots and violinplots of soil pH values with different properties of ponds
8. Boxplots and violinplots of soil electrical conductivity values with different properties of ponds

表3：桥园坑塘土壤pH值Wilcoxon秩和检验结果
Table 3: Wilcoxon rank sum test of pH value of soil samples in Qiaoyuan Park

对比项 Item	均值1 Mean Value 1	均值2 Mean Value 2	P值 P-value	结果 Result
上部采样点－对照点 U-samples vs. ck	8.266	8.263	0.8824	无显著差异 No significant difference
下部采样点－对照点 D-samples vs. ck	8.108	8.263	0.0011**	下部采样点极显著低于对照点 D-samples extremely significantly lower than control points
中心采样点－对照点 C-samples vs. ck	8.094	8.263	0.0079**	中心采样点极显著低于对照点 C-samples extremely significantly lower than control points
上部采样点－下部采样点 U-samples vs. D-samples	8.266	8.108	0.001**	上部采样点极显著高于下部采样点 U-samples extremely significantly higher than D-samples
上部采样点－中心采样点 U-samples vs. C-samples	8.266	8.094	0.0063**	上部采样点极显著高于中心采样点 U-samples extremely significantly higher than C-samples
下部采样点－中心采样点 D-samples vs. C-samples	8.108	8.094	0.6416	无显著差异 No significant difference
高坑塘－对照点 High ponds vs. ck	8.173	8.263	0.02*	高坑塘采样点显著低于对照点 Samples of high ponds significantly lower than control points
低坑塘－对照点 Low ponds vs. ck	8.171	8.263	0.06	无显著差异 No significant difference
高坑塘－低坑塘 High ponds vs. low ponds	8.173	8.171	0.97	无显著结果 No significant difference
干坑塘－对照点 Dry ponds vs. ck	8.124	8.263	0.002**	干坑塘采样点极显著低于对照点 Samples of dry ponds extremely significantly lower than control points
湿坑塘－对照点 Dry ponds vs. ck	8.223	8.263	0.35	无显著结果 No significant difference
干坑塘－湿坑塘 Dry ponds vs. wet ponds	8.124	8.223	0.01*	干坑塘采样点显著低于湿坑塘采样点 Samples of dry ponds significantly lower than wet ponds

注：
1. 均值1为对比项左侧采样点的均值，均值2为对比项右侧采样点的均值。
2. * P＜0.05，表示统计学上差异显著；** P＜0.01，表示统计学上差异极显著。

Notes:
1. Mean value 1 is the average value of the first checked items presented here and mean value 2 is the average value of the second checked items.
2. * P＜0.05 suggests a statistical significance, ** P＜0.01 suggests an extremely statistical significance.

照点，下部采样点的土壤电导率则高于对照点；在坑塘区域整体空间上，低坑塘土壤样本的电导率高于高坑塘和对照点，即较低位置的土壤盐分含量较多。湿坑塘与干坑塘相比，前者采样点的土壤电导率较高。

不同实验因素间电导率的Wilcoxon秩和检验（表5）表明，下部采样点的土壤电导率分别极显著地高于对照点、上部采样点和中心采样点，依次为：下部采样点下＞中心采样点＞对照点＞上部采样点。低坑塘采样点的土壤电导率显著高于对照采样点和高坑塘，可见含盐量与采样点相对位置的高低有较大关系，较低位置的土壤盐分较高。干坑塘和湿坑塘土壤电导率间无显著区别。以均值作为参考依据，下部

low ponds'. The pH value of soil samples collected from dry ponds is extremely significantly lower than control points' and wet ponds'. In terms of mean value, control points' pH is significantly higher than D-samples' and C-samples' by 1.91 percent and 2.09 percent, respectively. It is also 1.10 percent and 1.71 percent higher than those of high ponds and dry ponds, respectively. U-samples' is 1.95 percent higher than D-samples'.

3.2 Electrical Conductivity Analyses

Electrical conductivity values of soil samples vary from 0.21 to 6.26 dS/m. According to Figure 4, 4.44 percent soil samples in the study area are in mild salinization and all D-samples. 1.67 percent samples are in moderate salinization, all collected from the bottom centers of Pond 10 or 13. Electrical conductivity values of most D-samples are higher than the other samples on average.

To make the figures easier to understand, electrical conductivity values were transformed with logarithm to base 10 (Fig. 8). It can be seen that in terms of median, electrical conductivity values of U-samples and C-samples are lower than control points'; D-samples' electrical conductivity is the highest. Across the designed area the electrical conductivity of soil samples of low ponds is overall highest, indicating that the salinity of lower places is higher. Electrical conductivity of soil samples of wet ponds is higher than that of dry ponds.

Wilcoxon rank sum test (Table 5) reflects that the electrical conductivity values of D-samples are extremely significantly higher than those of control points, U-samples, and C-samples. Electrical conductivity values of soil samples in low ponds are extremely significantly higher than those of control points and high ponds. It discloses that soil salinity correlates closely with relative positions: the soil at a lower position has a higher salinity. There is no

表4：土壤盐渍化分级以及对作物的影响[14]
Table 4: Classification of soil salinization and impacts on crops[14]

土壤盐渍化分级 Soil salinization grade	土壤饱和提取液电导率（EC，dS/m） Electrical conductivity of saturated soil extract (EC, dS/m)	对作物的影响 Impact on crops
无盐渍化 No salinization	0＜EC≤2	无影响 No impact observed
轻度盐渍化 Mild salinization	2＜EC≤4	盐分敏感作物有影响 Salt sensitive crops are impacted
中度盐渍化 Moderate salinization	4＜EC≤8	只有耐盐碱作物能够生长 Only salt-tolerant crops can grow
重度盐渍化 Severe salinization	8＜EC≤16	只有少数耐盐碱作物能够生长 A few salt-tolerant crops can grow
非常严重的盐渍化 Very severe salinization	＞16	只有极少数耐盐碱作物能够生长 Very few salt-tolerant crops can grow

表5：桥园土壤坑塘电导率Wilcoxon秩和检验结果
Table 5: Wilcoxon rank sum test of electrical conductivity of soil samples in Qiaoyuan Park

对比项 Item	均值1 Mean value 1	均值2 Mean value 2	P值 P-value	结果 Result
上部采样点 – 对照点 U-samples vs. ck	2.644	2.745	0.2382	无显著差异 No significant difference
下部采样点 – 对照点 D-samples vs. ck	3.004	2.745	0.0002**	下部采样点极显著高于对照点 D-samples extremely significantly higher than control points
中心采样点 – 对照点 C-samples vs. ck	2.783	2.745	0.9514	无显著差异 No significant difference
上部采样点 – 下部采样点 U-samples vs. D-samples	2.644	3.004	0**	上部采样点极显著低于下部采样点 U-samples extremely significantly lower than D-samples
上部采样点 – 中心采样点 U-samples vs. C-samples	2.644	2.783	0.7684	无显著差异 No significant difference
下部采样点 – 中心采样点 D-samples vs. C-samples	3.004	2.783	0.0007**	下部采样点极显著高于中心采样点 D-samples extremely significantly higher than C-samples
高坑塘 – 对照点 High ponds vs. ck	2.699	2.745	0.6675	无显著差异 No significant difference
低坑塘 – 对照点 Low ponds vs. ck	2.927	2.745	0.0105*	低坑塘采样点显著高于对照点 Soil samples in low ponds significantly higher than control points
高坑塘 – 低坑塘 High ponds vs. low ponds	2.699	2.927	0**	高坑塘采样点极显著低于低坑塘采样点 Soil samples in high ponds significantly lower than low ponds
干坑塘 – 对照点 Dry ponds vs. ck	2.799	2.745	0.5169	无显著差异 No significant difference
湿坑塘 – 对照点 Dry ponds vs. ck	2.838	2.745	0.108	无显著差异 No significant difference
干坑塘 – 湿坑塘 Dry ponds vs. wet ponds	2.799	2.838	0.1617	无显著差异 No significant difference

注：
1. 均值1为对比项左侧采样点的均值，均值2为对比项右侧采样点的均值。
2. * P＜0.05，表示统计学上差异显著；** P＜0.01，表示统计学上差异极显著。

Notes:
1. Mean value 1 is the average value of the first checked items presented here and mean value 2 is the average value of the second checked items.
2. * P<0.05 suggests a statistical significance, ** P<0.01 suggests an extremely statistical significance.

采样点比上部采样点显著多累积了13.6%的盐分，比对照点多9.44%，低坑塘比高坑塘多累积8.45%。

3.3 pH值和电导率之间的关系

对土壤坑塘pH值和电导率的Wilcoxon秩和检验结果进行统计发现，对于坑塘内的不同位置，下部采样点的pH值和电导率分别与上部采样点、对照点都存在极显著差异（表6）：上部采样点的土壤pH值极显著地高于下部采样点，土壤电导率则相反；下部采样点土壤pH值极显著地小于对照点，电导率极显著地大于对照点。对于其余实验因素

significant difference between the electrical conductivity values of dry and wet ponds. In terms of mean value, the salinity of D-samples is 13.6 percent and 9.44 percent higher than those of U-samples and control points, respectively. Salinity of soil samples in low ponds is 8.45 percent higher than that of high ponds.

3.3 The Relationship Between pH and Electrical Conductivity

Statistics on the above Wilcoxon rank sum tests show that in terms of the position within a pond, pH values and electrical conductivities of D-samples are extremely significantly different with those of U-samples and control points (Table 6). The pH value of U-samples is extremely significantly higher than that of

表6：土壤坑塘pH值和电导率Wilcoxon秩和检验显著性检验结果统计
Table 6: Statistics on Wilcoxon rank sum test of pH value and electrical conductivity of soil samples

坑塘属性 Property	极显著差异（P<0.01） Extremely significant difference (P<0.01)	显著差异（P<0.05） Significant difference (P<0.05)
坑塘不同位置 Different positions in the pond	上部采样点-下部采样点（pH值、电导率） U-samples vs. D-samples (pH value and electrical conductivity)	/
	下部采样点-对照点（pH值、电导率） D-samples vs. ck (pH value and electrical conductivity)	
	上部采样点-中心采样点（pH值） U-samples vs. C-samples (pH value)	
	中心采样点-对照点（pH值） C-samples vs. ck (pH value)	
	下部采样点-中心采样点（电导率） D-samples vs. C-samples (electrical conductivity)	
高坑塘和低坑塘 High and low ponds	高坑塘采样点-低坑塘采样点（电导率） Soil samples of high ponds vs. soil samples of low ponds (electrical conductivity)	低坑塘采样点-对照点（电导率） Soil samples of low ponds vs. ck (electrical conductivity)
		高坑塘采样点-对照点（pH值） Soil samples of high ponds vs. ck (pH value)
干坑塘和湿坑塘 Dry and wet ponds	干坑塘采样点-对照点（pH值） Soil samples of dry ponds vs. ck (pH value)	干坑塘采样点-湿坑塘采样点（pH值） Soil samples of dry ponds vs. soil samples of wet ponds (pH value)

则只有pH值或电导率一项指标存在极显著或显著差异。可见同一坑塘内的高低位置因素对土壤pH值和电导率的测定结果有关键性影响。

将电导率取以10为底的对数，和pH值作散点图（图9），观察到图中上部采样点在pH值较高而电导率较低的区域分布较多，下部采样点则相反，多分布在pH值较低而电导率较高的区域。即坑塘内上部采样点普遍碱性较大、含盐量较低，下部采样点碱性较小、含盐量较高。中心采样点和对照点在各个区域分布相对均匀。

3.4 设计生态学手段与盐碱地改良景观绩效的关联

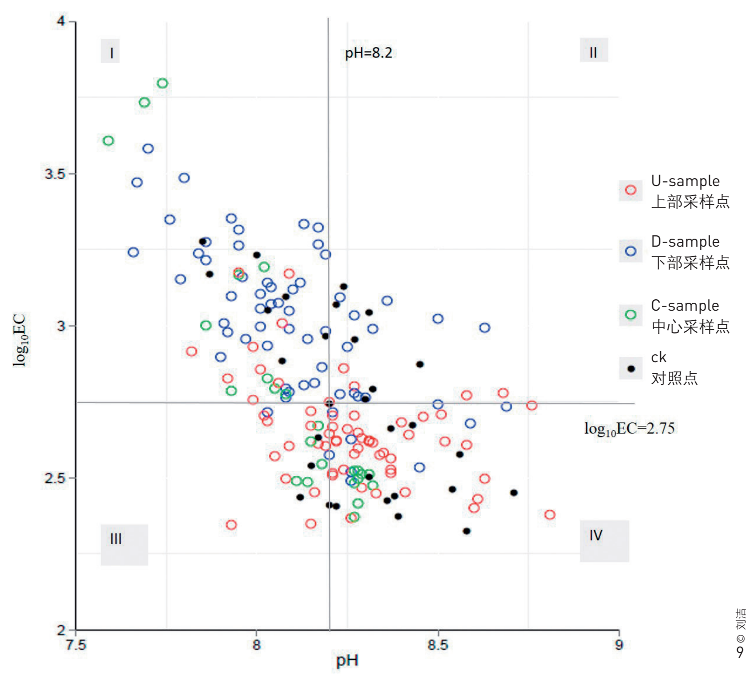
桥园公园原本的地势是由东北至西南逐渐降低，部分坑塘间也设置了水流通道，故目前形成了两条设计雨水流向（图10），即坑塘10→11→12→17→19→20→21（水流方向1）和坑塘13→14→15→16→18→21（水流方向2）。未标记水流方向的坑塘为旱坑塘，或与其他坑塘不连通。由于电导率受地势影响较大，因此取每个坑塘所有采样点电导率均值，得到沿水流方向电导率的变化（图11）。在两个水流方向上，虽然前两个坑塘电导率有所降低，但总体

D-samples, to which the electrical conductivity is opposite. The pH value of D-samples is extremely significantly lower than that of control points, and the electrical conductivity opposite as well. As to the other properties, significant difference is not discovered in both of pH and electrical conductivity at the same time. Therefore, relative position in the pond plays a key role in affecting the determination results.

A scatter plot (Fig. 9) of electrical conductivity values transformed with logarithm to base 10 and pH values reveals that most U-samples are in the zone with high pH value and low electrical conductivity, while the most D-samples are in the opposite zone. In other words, U-samples generally have a higher alkalinity and lower salinity. C-centers and control points are scattered relatively evenly.

3.4 Correlation between Designed Ecology Measures and Saline-Alkali Soil Amelioration Performance

Given the park's gently inclining terrain from the northeast to the southwest and the designed water passages connecting several ponds, there are two water flows (Fig. 10): Ponds 10→11→12→17→19→20→21 (Flow 1) and Ponds 13→14→15→16→18→21 (Flow 2). Dry ponds and isolated ones are not covered in the flows. The electrical conductivity plot shows a stronger correlation with terrain, so the electrical conductivity changes along the water flows and the mean values of all samples from each pond are revealed in Figure 11. Though the electrical conductivity values of the first two ponds in both flows are decreasing, they tend to increase overall. It indicates that



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9. 全部采样点土壤样品pH值和电导率（取以10为底的对数）散点图

9. Scatter diagram of electrical conductivity values (taken logarithm with the bottom of 10) and pH values

还是升高的趋势，表明含盐量随着地势降低而不断累积。这与同一坑塘中相对位置越低，含盐量越高的结果一致。

4 结论与讨论

4.1 结果与结论

研究结果显示：

1）桥园公园坑塘区土壤pH值范围为7.6~8.8，属轻度至中度盐碱地；电导率范围为0.21~6.26dS/m，少部分属于轻度和中度盐渍化。

2）对照点的土壤样品pH值相对较高，其均值分别显著高于土壤坑塘区的下部采样点、中心采样点、高坑塘和干坑塘1.91%、2.09%、1.10%和1.71%。

3）土壤样品pH值和电导率与采样点所处的相对位置有关：同一坑塘内，相对靠上的土壤采样点pH值较高、碱性强，不同位置处土壤电导率的大小关系为：下部采样点＞中心采样点＞对照点＞上部采样点。上部采样点pH值比下部采样点高1.95%，下部采样点比上部采样点显著多累积13.6%的盐分；在不同属性的坑塘间，高坑塘土壤采样点的pH值较低坑塘更高，低坑塘土壤电导率极显著大于高坑塘，低坑塘比高坑塘显著多累积8.45%的盐分。总体上，位于较高处的土壤采样点大

the salt tends to accumulate as the elevation decreases, which is also consistent with the finding that the lower position in one pond the soil is in, the higher salinity it is.

4 Conclusion and Discussion

4.1 Conclusion

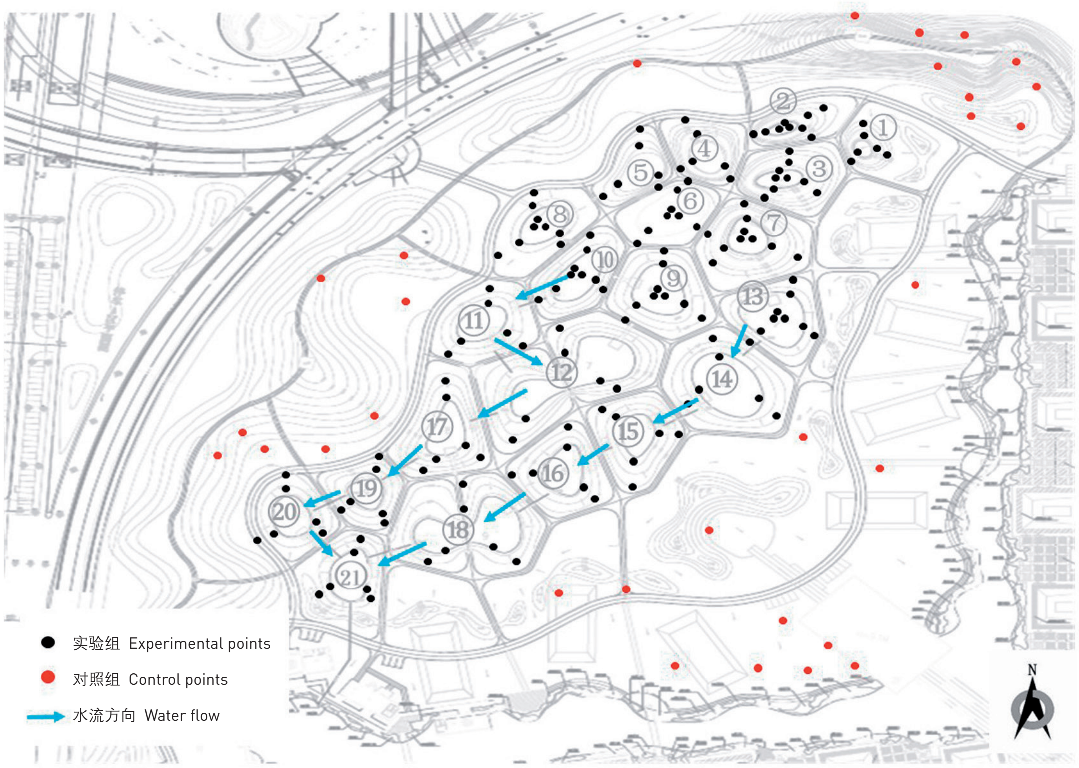
The research results show that:

1) The soil pH in the Qiaoyuan Park ranges from 7.6 to 8.8, which indicates light saline-alkali land. Its electrical conductivity ranges from 0.21 to 6.26 dS/m, partly in mild and moderate salinization.

2) The pH values of soil samples of control points are significantly higher by 1.91 percent, 2.09 percent, 1.10 percent, and 1.71 percent than those of D-samples, C-samples, and the soil samples collected from high ponds and dry ponds, respectively.

10. 桥园公园坑塘间水流方向示意图
11. 沿两条水流方向的坑塘内土壤样品电导率变化

10. The two water flows connecting the ponds in the Qiaoyuan Park
11. Line charts of electrical conductivity values along the two flows



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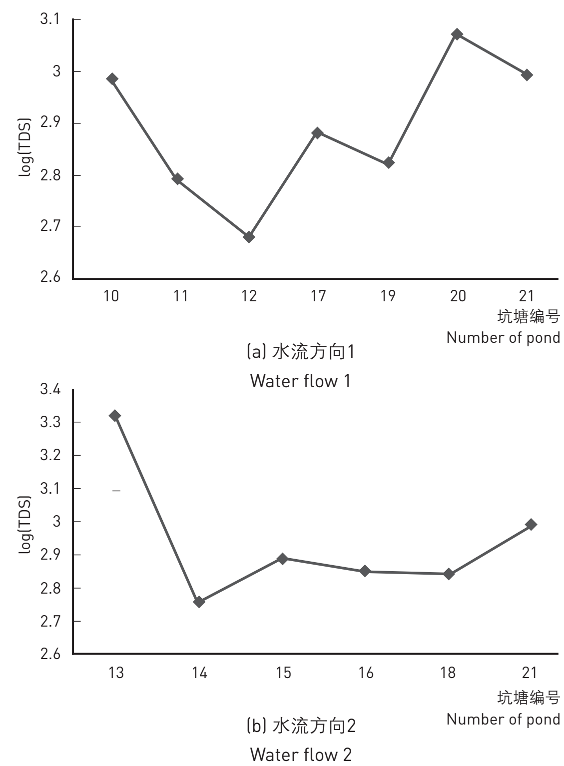

注：坑塘10、11、13土壤电导率较高，可能是由于这些坑塘受到了较多的人为影响，如设计后的改造、人工浇灌等。如深入探究空间上不同坑塘土壤的pH值和含盐量的变化，需要重新设计相应的生态学实验进行验证。

Note: The electrical conductivity values of Pond 10, 11 and 13 are relatively higher, which is probably due to human disturbances such as reconstruction and irrigation. New additional experiments are required to further explore the correlation between variations of soil pH and electrical conductivity with the spatial layout of ponds.

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多pH值较高而电导率较低，较低处的采样点相反。

4）整体上，随地势的降低，土壤电导率有升高的趋势，即含盐量累积。

综合以上研究成果，通过景观设计手段，桥园公园坑塘区域的土壤pH值明显低于非设计区域，并且不论是在坑塘内部微环境还是在坑塘区域整体空间上，都将土壤盐分累积在较低处，从而达到了显著排盐排碱的设计目的，改善了原场地土壤受污染、盐碱化严重等状况。

4.2 对结果差异的讨论

pH值和电导率测定结果分析表明，对照采样点的土壤碱性较强，电导率也相对较高。经与公园管理人员访谈调研得知，由于原场地本身较为低洼、土壤量较少，故建设过程中从天津东丽湖移来了部分土壤，用于补充园中各处建设所需土壤的不足。东丽湖地区地下水埋藏浅、矿化度高，是东丽区土壤盐碱化最严重的地区，土壤以氯化物滨海盐土为主，pH值一般为8.5~8.6[15]。加之公园原场地地势低洼，地下水位较低，地下水盐较易转化为土壤水盐，形成盐碱土。因此，可认为对照点土样能够代表公园原来盐碱化较严重的土壤状况，实验结果也说明设计区域的坑塘系统在降低土壤盐碱度方面的确起到了一定作用。

土壤酸碱度受成土母质、气候、植被、地形、人为等因素的影响[16]。就本研究场地尺度而言，土壤情况主要受植被、地形和人为等因素影响，成土母质和气候因素影响微弱。

4.2.1 植被影响

对照采样点植物种植单一，多为平坦的草地或裸地（图12）；而坑塘有高低、干湿之分，且有针对性地栽种乡土耐盐碱植物，如坑塘的最外缘种植一圈旱柳（*Salix matsudana*）、绒毛白蜡（*Fraxinus velutina*）、钓钟柳（*Penstemon campanulatus*）、元宝枫（*Acer truncatum*）、洋槐（*Robinia pseudoacacia*）、加杨（*Populus × canadensis*）等（图13）。研究发现，树木的枯落物进入土壤后，其有机质的腐化往往会使土壤呈酸性，且林木的根系呼吸富集大量CO_2，易

3) The soil pH and electrical conductivity show a correlation with relative position of the sampling. Within one pond, the higher part also has a higher soil pH. The gradient of salinity of different positions within one pond is D-samples > C-samples > control points > U-samples. The mean pH value of U-samples is 1.95 percent higher than that of D-samples, and the mean salinity of D-samples is 13.6 percent higher than that of U-samples. The soil pH of high ponds is higher than that of low ponds, while the electrical conductivity of soil in low ponds is extremely significantly higher than high ponds, indicating that salinity of soil samples of low ponds is 8.45 percent higher than that of high ponds. In other words, the soil samples collected from relatively high positions are with higher pH values and lower electrical conductivities, and those from relatively low positions are opposite.

4) Overall, salt accumulates as the elevation decreases.

Based on the above findings, through micro topographical design, Qiaoyuan's constructed ecosystem significantly drains away salt and alkali to the lower areas of the park, both within the pond and across the whole pond system, realizing its design goal. The pollution and salinization of the site have been mitigated.

4.2 Discussion

The above findings show that the soil pH values and electrical conductivities of control points are both higher than those of sampling points collected from the ponds. According to the park managers, this is probably because that part of the soil filled on the site was collected from the Dongli Lake of Tianjin during the construction. The soil in the Dongli Lake area was suffering from the worst salinization in the region due to the shallow groundwater of high salinity, as a typical chloride coastal saline soil and its pH value often ranges from 8.5 to 8.6[15]. Besides, the original site was low-lying with a low groundwater table, so the salt in the groundwater was easy to permeate into soil. These mean that the samples of control points can represent the original soil condition, and the experimental results prove the designed ponds' performance in saline-alkali soil amelioration.

Soil alkalinity is usually impacted by parent materials, climate, vegetation, terrain, human disturbance, etc.[16]In this site-scaled research, only vegetation, terrain and human disturbance are taken into account since parent materials or climate factors make little impact on the soil alkalinity.

4.2.1 The Impact of Vegetation

Vegetation of control points saw a less diversity, in forms of grasslands or bare lands (Fig. 12). However, the ponds have various designed elevations creating varied wetness conditions, and were planted with local saline-alkali tolerant plants such as *Saliz*

形成酸性物质，从而降低土壤pH值[17]。相比之下，草地并不具备这种特质。

4.2.2 微地形影响

一般而言，相同条件下，较高位置土壤的淋溶作用较强，pH值较低；较低洼处土壤pH值较高，土壤往往呈碱性[16]。桥园公园内不同标高的坑塘间的比较结果符合这个规律，且湿坑塘土壤pH值大于干坑塘，因为几乎所有的湿坑塘也均为低坑塘，干坑塘为高坑塘。但同一个坑塘中，上部采样点的土壤pH值却极显著大于下部采样点和中心采样点，可能与植物种植和人为影响（比如浇灌）等相关。

土壤电导率也与所在位置的高度有关。对于不同的坑塘，其标高相对位置越低，土壤电导率越大，含盐量越高，相反则含盐量低，即坑塘的设计可通过人工制造高差，将盐分积累在公园内相对位置较低的区域，从而缓解较高处土壤的盐化问题。此外，坑塘内上部采样点的土壤大多含盐量较低，下部采样点则较高。盐碱土形成的根本原因是可溶性盐类在土壤中发生水平和垂直方向的重新分布，导致盐分逐渐累积直到超过正常水平[18]。再加上桥园公园地区地下水埋藏较浅，加剧了土壤的积盐作用，因此，在地形、降水和水文地质共同作用下，越低位置的土壤含盐量越高。此外，在天津这样典型的盐碱地城市，即便微小的海拔变化都会带来水分、酸碱度和含盐量等土壤物理化学特性的变化。

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matsudana, *Fraxinus velutina*, *Penstemon campanulatus*, *Acer truncatum*, *Robinia pseudoacacia*, and *Populus × canadensis* (Fig. 13). Previous research has found that the corruption of organic matter of tree litterfalls would help soil turn acidic. Besides, root respiration would produce carbon dioxide which is easy to form acidity for soil ameolioration[17]. By contrast, grassland does not have this quality.

4.2.2 Impact of Micro Topography

Generally speaking, soil in a higher position sees a more intensive eluviation and has a lower pH with the other factors controlled the same. Soil of low-lying land has a higher pH and tends to be more alkaline[16]. In the Qiaoyuan Park, the results among high and low ponds are consistent with this. The soil pH of wet ponds is higher than that of dry ponds, while most wet ponds are also in lower positions and the dry ponds in higher. In one pond, however, the pH values of U-samples are extremely significantly higher than those of D-samples and C-samples, which is probably related with planting conditions and human disturbance such as irrigation.

Soil electrical conductivity is also related with relative elevations. Soil in a lower position has a higher electrical conductivity and a higher salinity, to which the higher position is opposite. In other words, the design of ponds can accumulate salt in the lower area to mitigate the soil salinization of higher positions. Similarly, in one pond the soil in a higher position has a less salinity compared with the lower positions. Fundamentally, soil salinity is resulted from horizontal and vertical redistribution of soluble salt[18]. Additionally, the groundwater table in the Qiaoyuan Park is so shallow that salt accumulation is aggravated. Hence, soil salinity is higher in lower positions under impacts of terrain, precipitation, and hydrogeology. Besides, Tianjin is a city of typical salt and alkali land, where even small changes in elevation may lead to a variation of soil physicochemical characteristics including moisture, pH, and salinity.

4.2.3 Design Inspiration

In conclusion, characterized for micro topographies and varied elevations, the design of ponds in the Qiaoyuan Park significantly contributes to draining away alkali from higher positions and accumulating salt in lower positions. It is also a commonly used hydro-melioration method in saline-alkali soil treatment[19]. Through plant identification and growth recording, it was found that plants on lower positions of slope were in a poor condition, so local plants with high salt absorption capacities are needed here. Meanwhile, alkali-tolerant plants will help reduce the alkaline in soil in the higher positions of slope.

12. 大部分对照点的采样地实景
13. 坑塘边缘种植的树木

12. The situation of the most sampling site of control points
13. Trees planted around the ponds

① 该数据为20世纪80年代全国第二次土壤普查结果。由于天津滨海地区的盐碱土尚未进行统一治理，近20余年来土壤盐碱含量变化不大，故认为上述普查结果可作为本文论证桥园公园景观绩效的对比依据。

② 天津市土地总面积取1.1917万平方千米，数据来源：http://www.tj.gov.cn/tj/tjgk/dlwz1/dlwz/。

① This figure is from the result of the Second National Soil Survey conducted in the 1980s. For few holistic treatments have been implemented, it can be assumed that the saline-alkali level of the coastal area of Tianjin has not changed much since the survey. In comparing the research data to this figure the landscape performance of Qiaoyuan Park can be proved.

② The total land area of Tianjin is 11,917 km^2. This figure is derived from: http://www.tj.gov.cn/tj/tjgk/dlwz1/dlwz/.

4.2.3 设计启发

综上所述，桥园公园的高低坑塘及其微地形的设计有利于借助自然雨水冲刷作用，有效地在坑塘较高位置处排碱，在较低位置处排盐，这也是盐碱土治理中常用的水利改良方法[19]。调研过程中通过对坑塘内植物的识别和生长状况记录发现，有些处于坡下部的植物生长并不好，故此处需要种植一些对盐分吸收效率较高的乡土植物。同时，在坡上部种植耐碱的乡土植物，利于解决土壤碱性较高的问题。

4.3 桥园公园模式的可推广性

天津市中度以上盐渍化土壤面积为9.7万公顷[20]①，约占全市土地面积②的8.1%；桥园公园土壤坑塘区域仅有4.44%属于轻度盐渍化，1.67%属于中度盐渍化，盐渍化程度明显低于市整体水平。公园也从昔日一块脏乱差的城市废弃地，成为了具有盐碱地改良、雨洪滞留、乡土生物多样性保护等多种生态系统服务的生态型公园，同时提供环境教育与审美启智、城市居民休憩娱乐的空间，与传统公园相比，更有助于环境和经济的发展，被认为是很好的“设计的实验”案例[21]。本研究通过生态学实验方法，验证了设计生态学指导下的桥园公园内利用土壤坑塘微地形变化建造了人工生态系统，成功达到了显著排盐排碱的设计目的，为滨海盐碱地城市公园和绿地景观设计提供了可推广和复制的模式。在具有类似特征的区域，可设计桥园公园这样的坑塘，以模拟自然界中土壤排盐排碱的生态过程，将盐和碱累积在某些位置，再辅以相应种类的植物，形成盐碱地适应性景观。此外，本案例的数据和结果可为桥园公园景观生态绩效的进一步研究提供科学基础。LAF

4.3 The Qiaoyuan Park as a New Paradigm

Data shows that the area suffering from moderate and severe soil salinization in Tianjin is about 97 000 hm^{2}①, accounting for about 8.1 percent of the total land area of the city[20]②. In the Qiaoyuan Park, only 4.44 percent soil samples are in mild salinization and 1.67 percent moderate, which is much lower than the overall level of the city. The park has turned from a derelict land to an ecological urban park with many ecosystem services such as saline-alkali soil amelioration, flood retention, and local biodiversity protection, providing spaces for environmental education and aesthetic enlightenment as well as recreation and entertainment. Compared with traditional parks, it contributes more to development of both environment and economy as a good case of “designed experiments,”[21] and its constructed ecosystem is proved to achieve the goal of saline-alkali elimination through micro topographies of ponds based on the concepts of Designed Ecology, which offers a new paradigm for coastal saline-alkali site improvement and green land design. In the areas with similar conditions, such ponds can be designed to accumulate salt and alkali in particular positions to simulate natural processes together with adaptive plant design. Besides, experimental data and results in this case also offer a scientific basis of further studies on the landscape performance of the Qiaoyuan Park. LAF

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