

塑造适应气候变化的水智慧型城市 ——南非开普敦干旱的经验与教训

MAKING CITIES WATER-WISE AND CLIMATE-RESILIENT — LESSONS AND EXPERIENCE FROM THE CAPE TOWN DROUGHT



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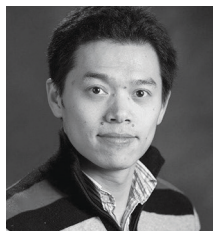


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摘要

目前全球已有一半的人口居住在城市，且这种面向城市的人口净流入仍将继续下去。在城市面临的所有挑战中，最紧迫的当属供水和卫生问题。2017~2018年，因连年干旱、严重缺水而导致的水资源危机使南非开普敦市频繁出现在世界各地的媒体头条中。幸运的是，象征着城市水资源耗尽的“零水日”并未到来。尽管如此，这场危机仍暴露出该市供水系统在面对持续气候变化时总体缺乏韧性，在气候适应性治理方面亦存在缺口。众多城市，尤其是南半球城市，可以从开普敦的遭遇中吸取鲜活的经验教训，了解如何通过强化治理来提高气候适应性。受访人马克·纽和吉娜·希尔翁戈长期关注开普敦的干旱问题，并致力于制定“开普敦干旱响应学习计划”。在本文中，受访人剖析了气候变化对开普敦干旱问题及城市供水系统的影响，并就干旱及水资源短缺的应对及预防措施提出了建议。本文亦简要介绍了由希尔翁戈提出的“适应性水敏城市框架”以及由二位受访人共同推行的“开普敦干旱响应学习计划”对提高开普敦城市韧性的促进作用。

关键词

开普敦；干旱；气候变化；供水；韧性

ABSTRACT

Half of humanity now lives in cities and the net inflow of population into cities will continue. Among all challenges faced by cities, the provisioning for water and sanitation is probably the most pressing one. From 2017 to 2018, the city of Cape Town in South Africa frequently made itself media headlines around the world, in many languages, for its severe water shortage due to consecutive years of drought that later resulted in a water crisis. Fortunately, the potential “Day Zero” when the city would run out of water, did not arrive. However, the crisis exposed a lack of resilience in the city’s water supply system in the face of ongoing climate change and a governance gap for climate adaptation. Many cities, especially those in the Global South, can learn from Cape Town’s experience and lessons on how to enhance governance to become more climate-resilient. Mark New and Gina Ziervogel, the interviewees, have been devoting themselves to studying about the Cape Town drought, and working on establishing the Cape Town Drought Response Learning Initiative. In this article, they analyzed the influence of climate change on Cape Town drought and the water supply system, and suggested effective methods to address and prevent the drought and water shortage. Ziervogel briefly described her adaptive and water-sensitive city framework while both of them revealed the role of Cape Town Drought Response Learning Initiative in making Cape Town more resilient.

KEY WORDS

Cape Town; Drought; Climate Change; Water Supply; Resilience

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INTERVIEWED AND EDITED BY LIU Wei TRANSLATED BY WANG Moying LI Huiyan

刘伟（以下简称刘）：南非开普敦市的干旱问题常被视为全球气候变化导致的严重影响对世界各地人们的警告。那么，全球气候变化究竟对2017-2018年的开普敦干旱问题有何影响？影响程度有多大？乐观估计，这一问题在未来几十年将会有怎样的发展趋势？

马克·纽（以下简称纽）：开普敦的城市供水几乎完全依靠地表水。导致其近期干旱问题的最直接原因是连续三年降雨量不足，而非高温造成的地表水蒸发。那么这是气候变化的结果吗？简单来说，并不全是。不过，尽管我们不能将极端干旱事件的发生完全归咎于气候变化，但它的确增加了开普敦地区的干旱风险。

作为世界天气归因联盟的成员，我们利用全球气候模型确定了这一难以察觉的归因风险。基于该模型的预估，我们发现，目前此种程度干旱发生的风险已经比气候未发生变化的情景增加了3倍，到2040年甚至将增加4~5倍。虽然目前此类干旱仍很罕见，但它正变得越来越普遍，并逐渐成为我们不得不经常应对的事件。它甚至可能每隔20年就发生一次，而不再是罕见的“黑天鹅”事件。气候变化已不是仅存在于遥远的未来，它正在发生且已经产生了影响。预防措施和适应性行动的介入已是刻不容缓。

刘：这一干旱事件是如何演变成水资源危机的？我们能从开普敦干旱事件中吸取哪些经验和教训，以在不断加剧的气候变化风险和不确定性面前提升城市供水系统的韧性？有哪些值得借鉴的供水和卫生保障措施？

纽：为开普敦市及周边农业区提供水资源的西开普省供水系统（WCWSS）主要由大坝和水库组成。水库储水完全依赖于降雨，因此整个供水系统极易受到气候不稳定变化的影响。最初建造这套系统的标准是应对平均50年一遇的旱灾——这听起来似乎还不错，但其前提是气候未发生变化，然而，正如我们所知，气候变化已经实实在在地发生了。同时，在人口增长等众多因素的作用下，水资源总体需求量也在增加。我们需要建立气候变化前景，以更好地了解气候变化将如何影响现有及未来计划增加的设施的效益，从而真正明晰在何时、以何种方式优化WCWSS开发计划才能提高其气候适应性。

LIU Wei (LIU hereafter): The Cape Town drought in South Africa was often considered a warning call for people around the world about the serious impact of global climate change. How exactly and how much did climate change contribute to the Cape Town drought from 2017 to 2018? What is our best estimate on the trend in the next decades?

Mark NEW (NEW hereafter): Water supply for the city of Cape Town relies almost exclusively on surface water. The main proximate cause of the recent drought was low rainfall over three successive years, rather than surface evaporation caused by high atmospheric temperatures. Was it due to climate change? The short answer is — not entirely. We cannot say that this particular drought was due to climate change, but it has increased the risk of drought in this region.

We, as part of the World Weather Attribution consortium, determined this fractional attributable risk using global climate models. Our models estimate that the risk of a drought of this magnitude has increased by roughly threefold compared with a world without any climate change and will increase even to five- or six-fold by 2040. While the drought like this is still a rare event, it is becoming much less rare, something we might have to deal with on quite a regular basis. It might even occur once every twenty years, rather than being a “black swan” or once a lifetime event. Climate change is not a thing of the future, instead, it is happening already and impacts us today. We can no longer postpone taking precautionary and adaptive actions.

LIU: How did the drought event escalate into a water crisis? What can we learn from it to make the water supply system more resilient to the increasing climate change risks and uncertainties, especially in terms of the provisioning of water and sanitation?

NEW: The Western Cape Water Supply System (WCWSS), mainly composed of dams and reservoirs, provides water for Cape Town and its surrounding agricultural areas. The reservoirs are entirely dependent on rainfall, making the system quite vulnerable to climatic variability and change. The WCWSS was designed to cope with droughts that might occur once every 50 years on average. This may sound not bad, but the design was based on the assumption of a stationary climate, whereas as we know it has been changing. At the same time, human’s overall water demand has been increasing due to a number of factors such as population growth. Scenarios of how climate change affects the yields from existing and the planned future augmentations will help us understand when and how to modify the WCWSS development plan to make it robust to climate change.

就用水需求而言，则需要通过社会协商塑造更具韧性的社会—经济共同体。鉴于每项增加水资源供给的措施都有其经济成本，因此需要进行权衡和协商，以尽可能兼顾供水系统的气候适应性与未来的经济效益。其中，适应性规划必不可少，而第一步就是了解系统的敏感性或脆弱性，并通过远景规划和适应性措施考量解决方案。如果在风险发生之初就进行这种概率或远景分析，并且真正把它作为标准方法坚持执行的话，我们就可以处于更加有利的位置，用更长远、更严谨的眼光看待新的改善措施。

水资源供需双方众多的不确定性使规划过程变得棘手。在我看来，我们需要正视这种不确定性，而非逃避。气候变化使本就不确定的供需平衡预测更加充满变数——其很可能会改变采取某些措施的时机，也可能会改变不同措施的相对适宜性，因为这些措施的稳健性和可靠性也会随气候变化而改变。因此，与其制定宏大的总体规划来建造可能在未来并无用武之地的大规模供水系统，不如一边持续推进对气候变化的深入了解，一边寻找灵活的决策途径。

总之，我们可以采取的最佳方案或许是以社会—经济共同体为前提，辅以能够增强供水能力的工程措施，并适当降低对未来效益的要求，做好每隔25年、甚至每隔10年就发生一次危机的准备，从而降低水资源系统的开发成本。

吉娜·希尔翁戈（以下简称希尔翁戈）：气候因素是开普敦干旱事件发生的主要原因之一——当初设计的供水系统本就无法应对降雨量连续三年低于平均水平的情况；但除气候因素外，还有许多其他问题也加剧了水资源的短缺，例如水资源系统治理方面存在的诸多挑战。在管理WCWSS时，国家水务部门的执行不力为开普敦市的供水系统埋下了隐患——由于前几年未划定明确的限制范围，对于水资源的

On the demand side, negotiation with society for a social-economic compact for higher tolerance of failure might be needed. There is an economic cost with every increment in supply augmentation, hence there is a trade-off and a negotiation between engineering the system as climate-proof as possible and the reliability of yield the system is going to provide. Adaptive planning is needed and the first step is understanding the sensitivity or vulnerability of the system, and incorporating this by means of scenario planning and adaptation pathways. We would possibly have been better positioned if this kind of probabilistic or scenario-based analysis had been done right at the beginning of the recent crisis and it really needs to become a standard practice that is done on an ongoing basis, looking well in advance and much more rigorously at the augmentation options.

Planning is made tricky by uncertainty in both the supply and demand sides. In my opinion, we need to embrace uncertainty rather than to run away from it. Climate change brings in additional uncertainty into those already uncertain projections of the demand-supply balance — it is probably going to change the timing with which certain supply augmentations have to come in place, or might also change the relative suitability of different augmentation options, as the robustness and reliability of different options vary in a changing climate. Therefore, rather than having a huge master plan for building a massive water supply system that might become redundant, we can think of a pathway where we have flexibility in decision-making through time as we learn more and more about what climate change is actually going to do.

Overall, the best option is probably some engineering to augment supply combined with a social-economic compact to agree to tolerate a slightly lower reliability, accepting going into crisis mode possibly every 25 or even every 10 years, thereby lowering the cost of developing water resource systems.

Gina ZIERVOGEL (ZIERVOGEL hereafter): One of the main reasons Cape Town experienced this drought is climate-related — the city's water supply system was not designed to cope with three consecutive years of below-average rainfall. But on top of the climate drivers, a number of other issues exacerbated the water shortage situation. As one of the aspects, there were challenges in the governance of the system. The national water department's engagement with the city was strained in terms of managing the WCWSS. This really put pressure on the system because in previous years restrictions were not enforced, and there had not been enough understanding of water availability around who was using what

可利用量、使用者及供应来源均不够了解，因此带来了一系列供水问题，比如谁可以使用哪里的水资源、可以使用多少等。

为了使开普敦更具气候适应性，我们需要更多地采用系统性方法。不仅要了解环境，更要了解人，从而理解供水系统所承受的压力。从长远来看，从严重依赖大气降水向利用地下水、泉水和河水等其他水资源的转型也十分必要。同时也需要保证对水利基础设施的长期资金支持，因为当危机到来时，基础设施的质量将决定整个系统的绩效。

此外，我们还需要意识到开普敦市存在严重的不平等现象，并将城市贫困人口的水资源与卫生需求考虑在内，因为他们是真正每天都在经历“零水日”的群体。城市与社会的多样性是我们的优势，但要想真正建成一座水资源韧性城市，我们应当顾及方方面面的因素。

刘：从治理的角度看，是什么让我们得以应对并度过了此次危机，又是哪些挑战使危机愈发严峻？为了使开普敦更好地适应气候导致的水资源压力，未来需采取哪些行动？

纽：在南非，我们拥有不同的水资源管理和供应模式，这种模式的主要挑战在于跨层级协调。西开普省的水资源供应非常依赖国家供水和卫生部来发挥其专业性，但近几十年来，他们基本上起不到任何作用。我们发现，正是这种对失灵的国家部门所提供的战略性供水规划的依赖导致了当前的危机。知识与能力的缺乏也是一项挑战。开普敦干旱事件刚刚发生的时候，市政府对于风险和脆弱性的考虑过于简单。如果采取了某种基于远景假设的方法，或至少对可能的后果进行某种定性评估，就可以为适时做出关键决策提供更加可靠的依据，从而有效地规避损失。

希尔翁戈：主要挑战有三：其一，市级、省级、国家级政府间缺乏协调；其二，政党代表、技术专家、战略管理人员之间缺乏合作；其三，以国家供水和卫生部为代表的政府机构能力不足。当然也有一

water. That created some questions around water supply, such as who was getting what and how much would be available.

For Cape Town to become more climate-resilient, we need more systematic approaches. We need to understand not only the environment but also the people in order to comprehend the pressures on the system. A long-term view diversifying from the reliance on the bulk of rainfall water to other water sources, such as groundwater, springs, and rivers is also necessary. Long-term funding is essential to support water infrastructure, as during a crisis the quality of this infrastructure is critical to the system performance.

Besides, we need to recognize the high inequality in the city and take the water and sanitation needs of the urban poor, who are effectively experiencing “Day Zero” daily, into consideration. Diversity in the city and society is our strength, but to really embrace a water-resilient city we need to take on all of these perspectives.

LIU: From a governance perspective, what enabled us to cope with the crisis and get out of it, and what were the challenges that made it more extreme? What kinds of actions are needed to make Cape Town more resilient to climate-induced water stresses in the future?

NEW: We have different water management and supply models in South Africa and coordination across levels is a major challenge. In the Western Cape, we are very dependent on the national Department of Water and Sanitation to be good at what it does. But we have had a bit of problems over the last couple of years during which period the national department has essentially been malfunctioning. We found that it is the dependence on the strategic water supply planning provided by a malfunctioning national department that largely contributes to the crisis we have right now. Knowledge and capacity gaps were also a challenge. At the start of the drought, the way the city government thought about the risk and vulnerability maybe was a little bit simplistic. If some kind of scenario-based approach, or at least some qualitative assessments of the likelihood of any of these end states, were carried out, it would have then provided a much stronger evidence base for critical decisions at the right time to navigate away from highly risky end states.

ZIERVOGEL: The main challenges include poor coordination between the spheres of government — city, provincial, and national governments, and poor collaboration between political representatives, technical experts, and strategic managers. There are also capacity challenges, particularly with

些正向推动因素，比如市政府与省政府共同支持企业发展，以及鼓励当地及国际相关专业技术的研发与应用。开普敦市的水资源管理部门能够开展跨部门协作，也能与政界人士合作推行应对措施。通过与政府、居民、企业建立联系并开展合作，城市用水量显著降低，最终使我们得以摆脱危机。

总的来说，我们需要加强合作。应对水资源问题已不仅仅是市政府的职责。我们必须做到跨部门、跨层级合作，同时也需要建立相互问责的制度与关系，以实现各级政府对水资源的有效管理；最后，还须加强市政部门及单位间的横向管理，并提升决策能力，以制定更具灵活性与适应性的政策。

刘：您曾提出“适应性水敏城市框架”（图1）^[1]。您是如何构思这一框架的？其他城市如何对其加以应用？

希尔翁戈：我一直关注气候变化适应性，试图了解个体和机构如何对气候影响做出反应，以及未雨绸缪有多么困难——因为似乎只有在受到气候变化的直接影响时，人们才会想要采取应对措施。在我看来，此次干旱事件是一个非常重要的契机，它让开普敦全市——无论是市民、企业，还是市政府和国家政府——都认识到了自身在重大气候影响面前准备不足。我真心认为需要利用这次机会，去体会我们能

national Department of Water and Sanitation. There are also some enablers, for example, the way city governments worked with provincial governments to support businesses and local and international expertise that was drawn on. Cape Town's water management department was able to work collaboratively across different departments and with politicians to implement responses. By developing these relationships and working collaboratively, both within government and with residents and business, there was a significant reduction in water use which actually got us out of the crisis.

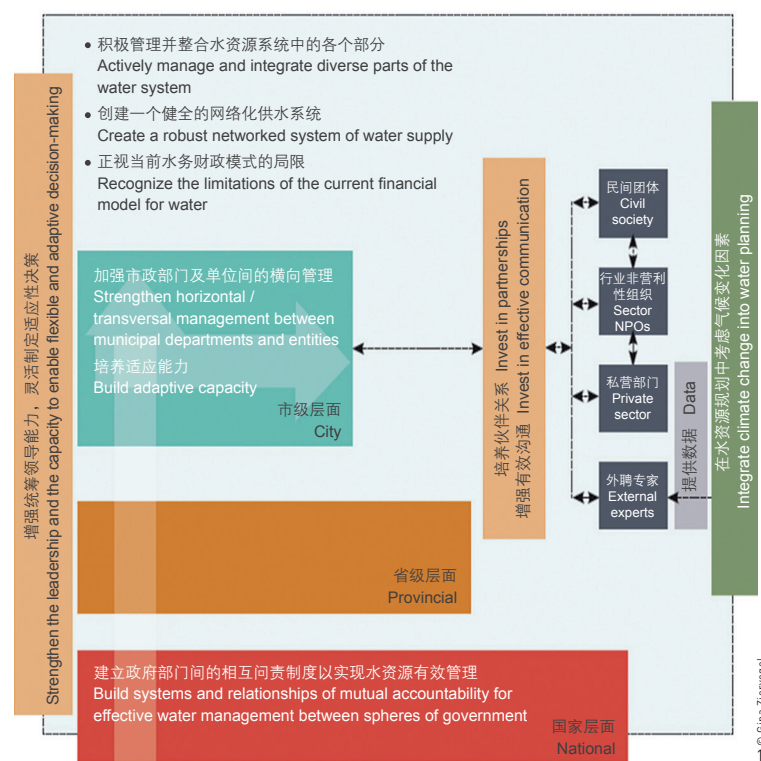
Overall, we need to strengthen partnerships. It is clear that the responsibility for water issues can no longer be just the remit of the city government. We have to collaborate across sectors and scales. We also need to build systems and relationships of mutual accountability for effective water management between spheres of government, enhance horizontal management between municipal departments and entities, and strengthen leadership and the capacity to enable flexible and adaptive decision-making.

LIU: You have proposed an adaptive and water-sensitive city framework (Fig. 1)^[1]. How did you come up with the framework and how can other cities operationalize such a framework for themselves?

ZIERVOGEL: I have always been interested in adaptation to climate change — how people and organizations respond to climate impacts and how hard it is to get people to prepare for that, because it seems that only when they are directly faced with it, they would then want to respond. For me, this drought has been a really important opportunity when I have seen the whole of Cape Town, from citizens across the board, businesses, to the city and national government, recognize their lack of preparedness to a significant climate impact. I really feel that we need to use this opportunity to experience what needs to be done in terms of climate change adaptation. We need to see how important it is to put in place measures now. So I hope that citizens who normally felt a bit disconnected from nature and climate impacts, now have a lived sense of what it might mean in the future, and therefore how important it is to get ready for future change.

Based on our experience, we came up with a synthesis of the key lessons for various stakeholders and processes, and a number of recommendations. We mapped the lessons in the adaptive and water-sensitive city framework so that it is easier to navigate through these lessons and link them to the recommendations. For other cities which might face similar challenges, they need to

1. 适应性水敏城市框架（图片来源：参考文献[1]）
1. Adaptive and water-sensitive city framework [source: Ref. [1]]



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为提升气候变化适应性做些什么，并明白未雨绸缪的重要性。因此，我希望那些之前认为自然及气候变化与自己关系不大的市民，从现在开始真切体会到问题的严重性，并做好准备应对未来的变化。

我们依据经验提炼出了综合各利益相关方及各个流程的关键性经验教训以及大量建议，并将其整合到适应性水敏城市框架中，以便于查看和借鉴。其他可能面临类似挑战的城市则需要根据其具体情况以及相关资源，为建设水敏城市制定长期的愿景策略。针对水资源供需情况的预测和基于场景预设的水资源规划需明确考虑气候变化的影响，从而确定适应性行动的优先级。在危机来袭之前，一定要保持警惕并率先评估本市的统筹领导能力和适应能力，以便迅速调配资源填补空缺。

刘：自前年起，二位开始致力于制定“开普敦干旱响应学习计划（CTDRLI）”^①。能否简单介绍该计划，以及它对提升开普敦韧性的促进作用？

纽：气候变化科学正在不断发展中，其实证基础愈发健全，对气候进行建模的能力也大幅提升。在适应性方面，随着人们不断尝试与气候变化适应性相关的举措，新兴的经验知识库也被逐渐建立起来。从研究与知识体系的角度来看，我们的确有必要努力记录当前正在发生的事情，判断哪些方法有效、哪些无效，从错误中学习、反思，并构建起知识库，以便在未来做出更具适应性的决策。这不仅关乎气候变化科学的发展，也是我们为了应对事物的不断发展而积累知识的过程。CTDRLI和子项目影像资料馆都是我们为开普敦建立知识库所做的尝试，这是非洲气候与发展计划小组、“重要对话”组织和CineSouth工作室共同努力的结果。

希尔翁戈：CTDRLI力图在人们对2017~2018年干旱危机的记忆尚为鲜明的时候，记录（包括录像）和描述从这场危机中获得的重要经验教训。这是从危机中吸取教训、总结新近经验的最佳时机，进而使人们了解气候变化及其相关风险、不确定性和影响，以及提前加强防范和提高适应能力的重要性。影像文件从不同人群的角度记录了这场危机的发生，也能促使更多个体和机构对此进行反思，并共同为提升城市整体韧性而努力。**LAF**

develop a vision and long-term strategy for what a water-sensitive city might look like in their specific context, along with associated resources. Climate change should be explicitly incorporated into water demand and supply forecasts and scenario-based planning for water resources to identify priorities for adaptation. It is important to be precautious and assess the leadership and adaptive capacity within the municipality before a crisis hits, so that resources can be mobilized quickly to address the gaps.

LIU: Since over a year ago, you have been working on establishing the Cape Town Drought Response Learning Initiative (CTDRLI)^①. Can you briefly introduce the initiative and what the role it plays in making Cape Town more resilient?

NEW: Climate change science is continually evolving; the evidence base is growing all the time and the ability to model the climate is improving. On the adaptation side, there is an emerging experiential knowledge base as people are trying things with regard to climate change adaptation. From a viewpoint of research and knowledge systems, we really have to be working hard to document what is happening to find out what works and what does not work, learn and reflect from mistakes, and build that knowledge base, so that we are enabled to make much better adaptation decisions as we go forward. It is not only about the climate change science evolving, but about our own knowledge of how to respond to what is evolving as well. The CTDRLI and Film Library are such attempts to build knowledge base for Cape Town, and it is a joint effort between African Climate and Development Initiative, Conversations that Count, and CineSouth Studios.

ZIERVOGEL: CTDRLI seeks to document (including recording videos) and capture significant lessons learnt from the 2017 ~ 2018 drought crisis when the memories are still fresh in people's minds. There is a window of opportunity here to learn from the crisis and draw on people's recent experience, about climate change and its associated risks, uncertainties, impacts, and the importance of enhancing preparedness and adaptive capacity ahead of time. The videos from the perspective of different people give us a chance to reflect on what happened. They also provide a point of engagement for other people and organizations to reflect on the drought and make deliberate changes that can help to make us more resilient as a whole. **LAF**

REFERENCE

[1] Ziervogel, G. (2019). Unpacking the Cape Town Drought: Lessons Learned. Retrieved from <https://www.africancentreforcities.net/unpacking-cape-town-drought-lessons-learned/>