Thirsty Cities

Shared Water Heritage in the Small Island States of the Dutch Caribbean

Loen, S.S.

Publication date
2021

Document Version
Final published version

Published in
LDE Heritage Conference on Heritage and the Sustainable Development Goals

Citation (APA)
Loen, S. S. (2021). Thirsty Cities: Shared Water Heritage in the Small Island States of the Dutch Caribbean. In U. Pottgiesser, S. Fatoric, C. Hein, E. de Maaker, & A. Pereira Roders (Eds.), *LDE Heritage Conference on Heritage and the Sustainable Development Goals: Proceedings* (pp. 370-396). TU Delft OPEN Publishing.

Thirsty Cities: Shared Water Heritage in the Small Island States of the Dutch Caribbean

Suzanne Loen

LILA Living Landscapes and Delft University of Technology, The Netherlands, Suzanneloen@lilalandscapes.nl, s.s.loen@tudelft.nl

Abstract

Securing fresh water supply on the Dutch Caribbean islands, former colonial overseas territories of The Netherlands from the 17th century, always has been, and still is, a challenge. Between 1904 and 1915 the cartographers Werbata and Jonckheer drew the first topographical maps of the islands. Detailed data was needed for the (re-)development of fresh water management system based on rainwater harvesting. The re-development of this decentralized water system as envisioned by governor De Jong van Beek en Donk was stopped short due to the regions oil boom. The water intense oil industry turned to groundwater exploitation and seawater desalination. Post oil Dutch Caribbean communities still rely predominantly on energy intensive desalination plants for their water supply. The destructions of Hurricane Irma on Sint Maarten in 2017 exposed the vulnerability of this system. Decentralized fresh water management systems enabling island communities to become more self-sustaining in the face of climate change and disaster are needed. In the field of water management there is growing acknowledgement that nature based solutions (NBS) offer an "alternative approach to increasingly relying on engineering solutions". Heritage inspired design and solutions, learning from vernacular and historical systems and practices, has the potential to add to the body of knowledge, possible strategies and solutions to manage fresh water resources sustainably and cope with the consequences of climate change. This paper therefor investigates the development of fresh water management systems and strategies in the Dutch Caribbean island of Curaçao during colonial rule. The Werbata-Jonckheer maps are an important source in this investigation for the development of a first landscape typomorphological overview of fresh water supply systems.

Keywords

Heritage inspired design and solutions, rainwater harvesting, storm water storage, water supply, micro catchment and soil storage systems, climate resilient fresh water management.

1 INTRODUCTION

"Venice is in water and has no water" (Historian Marin Sanudo, 1466-1536 qtd. in Distefano, 2016)

This observation still holds true for most small island states world wide then and now. Small Island States (SIS) of the Caribbean, like oceanic SIS the world over, are limited in geographical space and natural resources. Sustainable management of water resources can be especially difficult due to economic specialization in tourism and/or agriculture with often high levels of (seasonal) water consumption (Kliot, 2010, pp. 330). This gives rise to the special needs and circumstances of SIS (John & Firth, 2005). According to Acevedo "Fifteen Caribbean islands are in the top-25 positions of most tropical cyclone disasters per square kilometre" (Acevedo, 2016). In 2014 The World Bank. established the Small Island States Resilience Initiative (SISRI) program to help build their resilience to climate change and natural disasters (The World Bank and Global Facility for Disaster Reduction and Recovery (GFDRR), 2016).

Securing fresh water supply on the Dutch Caribbean islands, former colonial overseas territories of The Netherlands from the 17th century, always has been, and still is, a challenge. Without naturally occurring surface water and quickly depleting ground water resources the island communities completely depended on rainwater harvesting to secure their water supply. Governor De Jong van Beek en Donk of Curaçao, deployed between 1901-1909, who found the island agricultural sector in disrepair and many of its residents in deep poverty was convinced that innovation on the drought stricken islands water management system was needed (Van der Krogt 2005; Van Soest 1977). At the turn of the 19th century the Dutch government acknowledged the dire water supply circumstances and gave Indo-European[1] cartographer J.V.D. Werbata commission for the mapping and survey of its Caribbean territory. Peter van der Krogts research on the cartographer and the creation and development of the maps reveal that the commission was indeed intended to provide detailed information on the topography of its terrain to restore, upgrade and expand a vernacular decentralized rainwater harvesting system (Van der Krogt 2005; Renkema 1981). This system, consisting of dams to direct water and store water making use of the sloping terrain, was thought to be beneficial for the islands ailing agricultural sector and its communities. The development of the rainwater harvesting system as envisioned was stopped short by the oil boom. Due to the profitable oil refinery industry between 1918-1950 the Dutch Caribbean region became one of the first regions in the world who could afford energy intensive seawater desalination plants (Cooley, Gleick & Wolff, 2006). Today the Dutch Caribbean islands are among Qatar and Bahrein with the highest desalination capacity in the world (Jones, 2010). When hurricane Irma hit the island of Sint Maarten in 2017 desalination plants and storage tanks were demolished, leaving inhabitants and businesses exposed to water insecurity. A lack of decentralized and off the grid low tech water supply systems to enable communities to be more self-sustaining in general and in case of emergency in particular is exemplary for many small island (developing) states. Low tech and site specific solutions are needed. Studying historical and vernacular water management systems of the island could provide knowledge, inspiration and clues for the future.

1.1 HERITAGE INSPIRED DESIGN AND SOLUTIONS

According to Brears (2020) nature-based solutions (NBS) refer to "ecosystem-based approaches, biomimicry and biodiversity" and offer an "alternative approach to increasingly relying on engineering solutions" in the face of climate change. In addition to the concept of nature-based solutions the concept of heritage inspired design and solutions is a much-needed step forward towards an integrated and holistic approach of spatial planning and design in general and water related design and management in particular. Hein argues in Adaptive Strategies for Water Heritage that "policy makers and designers can work together to recognize and build on the traditional knowledge and skills that old structures embody" to "help us develop sustainable futures for cities, landscapes and bodies of water" (Hein, 2019). As a pendant to eco-system services in the nature-based approach Karen Gysen introduces the concept of heritage-system services in the heritage based approach (Gysen, 2018). Kosian and van Lanen in 2018 stress the importance of integrating historical spatial analyses in the so called 'climate stress-tests' that are being carried out in the context climate adaptation strategies to predict and depict flooding and inner-city heat risks. According to Kosian and van Lanen (2018) historical spatial analyses, incorporation of historical water systems, natural landscape dynamics and urban morphology in the analyses and modelling,

1 Indo-Europeans, also known as Euresians, Dutch Indonesians or Indos, held European legal status in the former Dutch East Indies but were of mixed Dutch and Indigenous Indonesian descent as well as their descendants today. Indos are associated with colonial culture of the former Dutch East Indies, a Dutch colony in Southeast Asia and a predecessor to modern Indonesia after its proclamation of independence shortly after World War II.(Van Imhoff & Beets, 2004)

is essential for accurate climate stress-test calculation. Kosian and van Lanen argue that in their proposed method of "history integrated solutions" heritage "can be applied both as inspiration and as a mean towards the solution" (Kosian & van Lanen, 2018).

Kosian and van Lanen were not the first to address this concept of heritage inspired or "history integrated" approach. In their 2006 publication Springs of Life: India's Water Resources environmental and water resource experts Pangare, Pangare & Das (2006) documented the tangible and intangible aspects of traditional water systems in India to show amongst others "the ways in which communities live and interact with water...and their common-sense solutions to local water problems". The authors express hope that "their account will be useful to anyone...in any part of the world working to address water related issues". For the authors the documentation of the "broad spectrum" of traditional water systems served not only the preservation of the systems in question but also explicitly served the greater goal of acquiring knowledge and inspiration for water related issues worldwide. By subsequently developing a systematic overview of India's traditional water systems Pangare & Pangare (2015) the authors argue that "traditional water harvesting techniques and water management systems can provide valuable lessons for today". While Pangare & Pangare acknowledge that "traditional water systems cannot meet the water needs of today" they do "demonstrate their significance and relevance to present times" challenges. They argue that "if traditional systems are revived and protected they can still meet part of the water demand in the ecosystem within they function" (Pangare & Pangare, 2015).

The apparent lack of historical awareness of policy makers, engineers and spatial planners and designers in the development and execution of climate adaptation strategies, as addressed by Kosian and van Lanen (2018), Hein (2019) and Pangare & Pangare (2006;2015), demonstrates the need to bring more attention to the heritage inspired approach as a valuable contribution to the nature based approach and the engineering approach. Within the scope of the Thirsty Cities research project I aim to bridge this gap with a focus on water resource management in the (former) Dutch territories where, in contrast to flood risk management, the engineering approach still dominates the sector. My chapter "Thirsty Cities: Learning from Dutch Water Supply Heritage"(Loen, 2019) showed "the potential heritage contains for creating an integrated approach to water supply, landscape conservation and water-secure livable cities" (Hein, 2019).

This paper focuses on the development of a typo-morphological overview, building further on Pangare and Pangare's systemic overview to create historical awareness and to develop a foundation for future studies that investigate the potential of water heritage "as inspiration and as a mean towards the solution" in future developments.

- Part 2 of this paper elaborates on the method of typo-morphological research and the materials used;
- Part 3 provides a short overview of the development of water management systems in the Dutch Caribbean in general and the typologies of Curaçao in particular;
- Part 4 provides conclusions and discussion.

2 METHOD & MATERIAL

This paper focuses on developing a first typo morphological overview of fresh water management systems. The research method that I am using in this study on the development of historical water systems and typologies in relation to their context builds upon work of academics, designers, planners and researchers in the field of heritage studies, (historical) geography, hydrology, landscape

architecture and urban planning. Needless to say, this method is in development and tested on the case study of the Dutch Caribbean Islands. Below I provide a condensed overview of the methods and works that have informed the method used in this study.

2.1 WATER SHAPES, LANDSCAPE AND PEOPLE

With the publication of 'Zee van Land' (Sea of Land) (Reh, Steenbergen and Aten, 2005), landscape architectural and contextual aspects of water management systems where for the first time put centre stage. In their landscape architectural analyses of the anatomy of monumental Dutch polder-drainage systems the authors introduced the layered approach. This type of landscape analyses explains and puts emphasis, through drawings, on the interaction between natural, cultural and architectural layers. In 'Haard en Horizon' (Hearth and Horizon) Zwart and Bobbink (2004) introduced the concept of beeldtypen (image types) for the analyses of gardens and parks. In addition to these publications with a focus on 'grand designs' with Land inSight (Bobbink, 2009) and Water InSight (Bobbink & Loen, 2013) the authors shift the attention to the vernacular everyday Dutch landscapes. Both books provide an overview of the historical development, typical steppingstones and spatial characteristics of cultural landscapes. In their 2006 publication Springs of Life: India's Water Resources Pangare, Pangare & Das analysed traditional water systems in India. The study focuses on the relation between the water systems and their social, cultural and geographical context and the regions climate. The role of the people and communities constructing and managing the water system, most often women, is explicitly highlighted. Building upon "Springs of Life" Pangare and Pangare published a systematic overview of traditional water systems of India in 2015. Although the authors admit that these systems are not able to meet current water demand their investigations objective is "to raise awareness of the systems and the communities and ecosystems they serve and may serve as inspiration for the future" (Pangare & Pangare, 2015). As water resource experts and environmentalist their studies do not comprise spatial or typological analyses. In that regard the European Interregial researchproject 'Water Shapes' (from 2007-2013) is an invaluable study with a primary focus on the shape of historical water systems, artefacts and their usage. The aim of this collaborative project between scholars from Italy, Spain, Portugal and France collaborated was to "create a systematic approach for enhancing knowledge relative to architectural artefacts related to water, by a thematic database.." and to " increase awareness at European and extra-European level of the need to preserve and enhance tangible and intangible heritage assets connected to water because "climate change and growing scarcity of water makes it unceasingly urgent to reflect on the fundamental role of water sources... not only concerning its use but also its cultural and artistic significance" (Genovese & Porfyriou, 2012). A different take on water is introduced in the body of work by Mathur and Da Cunha (landscape architect and architect respectively) and most notably in the latest publication 'The Invention of Rivers' (Da Cunha, 2019). Da Cunha argues that the "colonisation" of water by geographers has forced the substance of water into waterbodies and formal shapes and has led to the artificial, and in their opinion destructive, division of water and land meanwhile ignoring the hydrological cycle and natural dynamics of the context. Mathur and Da Cunha rather speak of different states of wetness, be it clouds, fog, rain or liquid, then of water and waterbodies.

Building upon the methods, concepts and ideas mentioned above the following aspects are taken into account in the method of typological analyses of the water systems:

Shape, context, symbolic representation, hydrological cycle, time, authorship, management and everyday usage

2.2 MATERIAL

The primary material for this study are the Werbata-Jonckheer maps (1911-1915) of the Dutch Caribbean Islands. The maps were drawn by Indo-European cartographer J.V.D. Werbata.
The government commissioned the task to a cartographer from the East Dutch Indies because they were familiar with mapping sloping and tropical terrain. Born in then Dutch colonial territory of Padang, Indonesia he was commissioned by the Dutch Government to survey the islands and draw the maps of the islands of Aruba, Bonaire, Curaçao, Sint Eustatius and Sint Maarten. The maps were commissioned in light of much needed improvement of the islands water supply system. The maps therefor provide detailed information regarding the landscape, water utilities and even seasonal water fluctuations (fig. 1) (Van der Krogt, 2005). This research focuses in particular on the leeward island of Curaçao, and to a lesser degree on the windward island of St. Eustatius (Sint Eustatius). For both islands, at some time in history important trading ports on the regional and global market, there is relatively more research and information available.

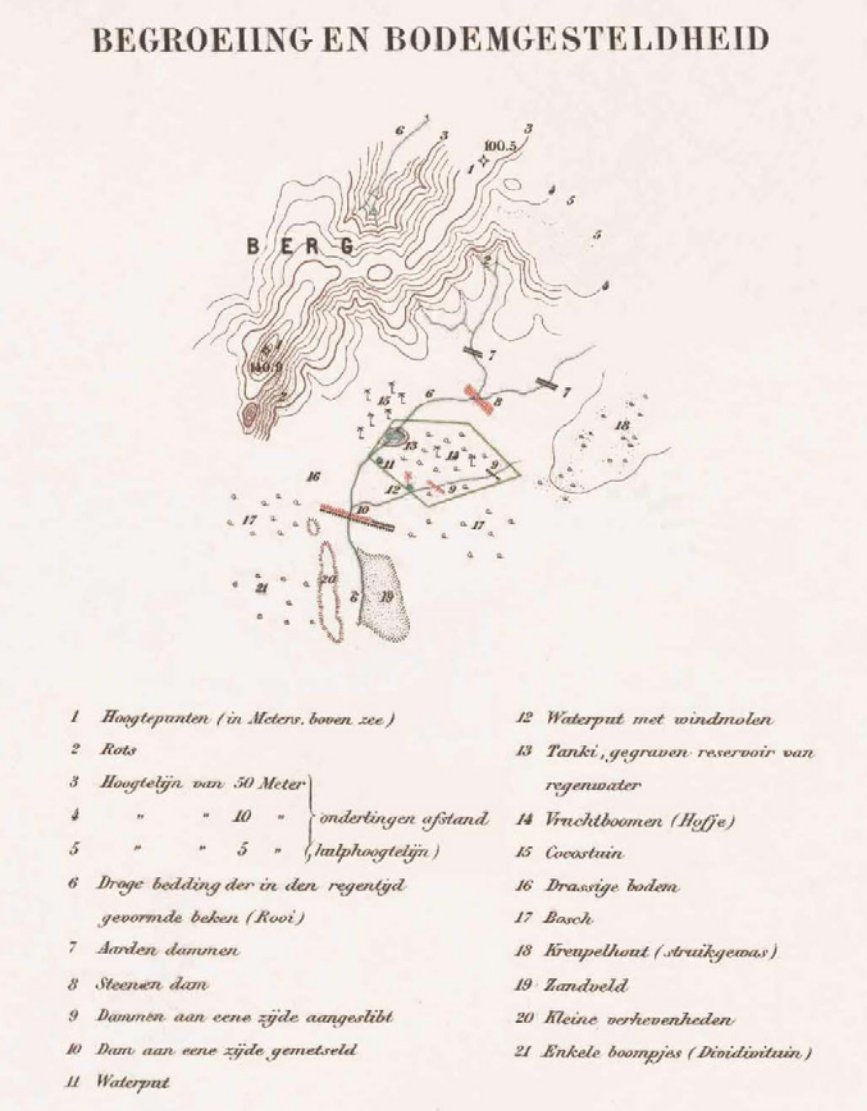

FIG. 1 Detail Legend of Curaçao Map indicating a.o. 6) rooi or dry bed brook filled with water during rainy season, 7) earthen dams, 8) stone dams, 11) water well, 12)waterwell with wind-powered motor, 13) Tanki, dug reservoir voor rainwater and 19) zandbed. Maker: Werbata-Jonckheer. Source: authors own.

3 FRESH WATER MANAGEMENT AND WATER HERITAGE OF THE DUTCH CARRIBEAN[2]

2 The terms West Indies, Antilles and Caribbean are used interchangeably, there is no general agreement on definitions of these terms (Blouet & Blouet, 2010)

In almost every study related to the subject of (historical) fresh water management the researchers report a lack of research on their subject in the (Dutch) Caribbean. Subsequently I can also start of by stating that the subject of historical development of water systems in relation to spatial development in the Dutch Caribbean is relatively under researched. However, for the islands of Curaçao and Sint Eustatius, that at some time in history rose to global importance in the international trade of goods and oil, relatively more research and resources on the subject is available. Renkema's study into the plantation economy of Curaçao has a strong focus on the water supply system (Renkema, 1981). In 2017 Van Keulen studied the *regenbakken* (cisterns) on St Eustatius (fig. 17), Pulsipher & Goodwin (1982; 2001) research on water management on Montserrat (neighbouring St Eustatius) provides insight in traditional water catchment systems. By putting together the scattered pieces of the puzzle it is possible to get an informed idea of how water supply developed in the colonial period.

3.1 CURRENT STATE OF WATER & LAND

The Dutch Caribbean are part of the Lesser Antilles, an island 'arc' comprising of three island groups: Leeward Islands, Windward Islands, and Leeward Antilles islands of Saba, St. Eustatius and St. Martin, in the Netherlands known as the S Islands, are part of the northern Leeward Islands group of which the Virgin Islands and Guadelope are more well known and also significantly larger. The Windward Islands group consist of amongst other Barbados, Grenada and Trinidad and Tobago. To the south, off the coast of Venezuela, are the leeward islands of Aruba, Curaçao and Bonaire. In the Netherlands we speak of the ABC Islands and the S islands. Saba and St. Eustatius are geologically active vulcanic islands, while St. Martin, Aruba, Curaçao and Bonaire are sedimentary Islands. (Garmon et al., 2017)

The islands lie in a maritime tropical air mass, with average annual temperatures of about 26.7 C and little seasonal temperature variation (Blouet and Blouet, 2010). Aruba, Curaçao and Bonaire are part of the southern Caribbean dry zone outside the hurricane belt. However hurricanes do hit the ABC islands. Historically the islands were considered fit for livestock grazing, also salt export, mineral mining and wood exports were important before they were impacted by the oil boom (Schmutz, Potter and Modlin, 2017). Cash crop plantation for cotton and sugarcane never became viable due to unfavourable conditions such as water scarcity and competition form large overseas plantations in the US and South America (Renkema, 1981). Curaçao is the main and largest island of the three and has a land area of about 444 km^2. It has the largest population of 158,986 and has a population density of 358 people per km^2 (Central Bureau of Statistics Curaçao). Post oil the tourist industry developed on the ABC islands. In 1997 the historic area of Willemstad, the capital of Curaçao, was declared a UNESCO Heritage site.

It's highest peak is the Mt Christoffel at 372 m. The moderate height differences clouds from being pushed to higher cooler atmosphere and rain down on the island. Annual rainfall varies extremely but has an average of 550 mm. January – September are the dry months, October – December is the wet season. The irregular rain patterns and periods of severe droughts of the ABC islands have always been a source of much speculation. Upon arrival in 1634 Van Walbeeck already mentions in his logs that "the island is dry but that they heard that it used to rain more frequently" (qtd in Renkema, 1981). The overhanging clouds that refuse to descend from the sky in form of rain are notorious.

In 1818 the Nederlandse Huishoudelijke Maatschappij (a local NGO) proposed to organize a competition to collect ideas on "how to help turn the clouds into rain, to prevent droughts" (Renkema, 1981). In his 1962 publication "Hydrology, Water Conservation, Erosion Control, Reforestation and Agriculture in Curaçao" P.C. Henriquez (a local governor and chemist) argues that the island is subject to a rain cycle of 6 years. Only one or two times in six years there is significant rainfall. According to Henriquez all was not lost if Shell oil refineries would stop pumping groundwater and a system of small dams would implemented to restore green cover and stop erosion (Enriquez, 1962). Unfortunately, non of his advises were followed up (Van Soest, 1977). Schmutz et al. (2010) also mention the assumption that the ABC islands once had a much wetter climate and refer to a hypothesis held by German geologist Karl Martin, the first to study karst caves on the ABC islands, in the 1880's. Martin suspected that one type of karst cave owes their existence to periods with significant higher rainfall.

3.2 A SHORT HISTORY OF LAND AND WATER

"...man finds to his dismayed surprise that he conquered the forest too well. He finds that although too much forest was a handicap to his progress, the absence of forest is an actual menace to his agriculture, his water supply, and to his very existence." (Gill 1931 qtd. in Westerman 1952)

With this quote Westerman illustrates in his report 'Conservation in the Caribbean' (Westerman, 1952) the dire state of the forest in the Dutch Caribbean, the impact of deforestation on the water cycle and fresh water resources and the lack of efforts for conservation and reforestation. The relation between land clearing and deforestation on deterioration of soil and water resources was well known in the Caribbean. One of the worlds earliest legally protected nature reserves is Main Ridge Forest on the island of Tobago, that became protected by the Crown in 1776.

According to Derix (2016) the landscape and vegetation in the Lesser Antilles changed due to fluctuations in geological and climate conditions and the impact of human activity. Derix defines four periods where human activities and resource exploitation had their distinctive impact on the green cover and hydrological cycle. Below fallows a short history of water related developments in Curaçao.

3.2.1 Pre ceramic – slash and burn

In pre-Columbian time the islands were semi permanent inhabited by Amerindians. Their settlements were oriented on the coastal mangrove forest were fresh water could be found on the foot off cliffs and in the cave system. Ancient water sources can be found in the Hato caves (Debrot, 2009). The land was covered with dry forests. The Arawak or Caquetio tribes would cultivate the land with slash and burn practices. Pollen research suggest large scale forest clearing and land erosion in that period.

3.2.2 Ceramicage – Small scale forest clearings and mangrove clearings with slash and burn

In the ceramic era the settlements became more sedentary and horticultural subsistence practices developed. The settlements moved more inward uphill to terrain more suitable for agriculture. In this period native inhabitants had profound influence on the natural vegetation (Harris 1965; Watts 1987 in Day, 2010). There is however little known about the way the Amerindian people secured

their water supply other then obtaining water from the karst. Research by Mary van Soest, a Curaçao resident, who has made an inventory of so called *karstbronnen* (karst springs) and *waterkuilen* (water holes) (MOWIC 2016) and fieldwork by Debrot (2009) suggest that the Caquetio people dug *waterkuilen* or pos di pia (water holes or foot wells) and that this practices and some of these elements may have survived and / or came in use by landowners and/or the enslaved Afro-Caribbean community.

3.2.3 Spanish rule 1499-1634 – Large scale land clearings

Although the Spanish spoke of Islas Inutiles (useless islands) the impact of the exploitation of the wood resources and agricultural practices can be felt up until today (Blouet & Blouet, 2009). Pollen research indicates large scale land clearings and deforestation in early colonial time of mangrove forest and dry forest for brazilwood, a textile dye. The import of cattle for grazing prevented regrowth of green cover. There was intensive mining of salt, chalk, phosphate (Derix, 2016). Indigenous agricultural and water management practices must have been observed by the Spanish while wielding their power and control over the native people and their existing water sources for their own convenience. In 1515 a mass deportation of the indigenous people to the cash crops plantations in the region was carried out. Upon arrival of the Dutch in 1634 the Caquetio population had grown again and outnumbered the Spanish (Hertog, 1968).

3.2.4 European colonial subsistence farming and last stage land clearings

Van Walbeeck, the first Dutch West Indian Company (DWIC) director of the Island until 1639, described Curaçao as covered with forest (Teenstra 1836 in Derix 2016). Walbeeck built a fort and castle at St. Anna Baay near a water source to protect water supply which is depicted in the 1715 map (fig.2; fig.3). On the 1715 maps also other watering places are indicated. In absence of Dutch governing bodies the DWIC were also responsible for securing public water supply (Renkema, 1981). Public wells were established to secure free access for watering cattle. To secure food supply the DWIC relied on the produce of the Caquetio people and African enslaved labourers. After a mass killing and deportation of Caquetio people by the DWIC there were only 75 Caquetio people left on the island (Hartog, 1968). They were spared to secure the food supply. The unfavourable conditions of the land however prevented the establishment and development of commercially successful cash crop plantations. The first plantations that were established were managed by the DWIC, so called compagnietuinen, but due to a lack of know-how, time and money they never flourished (Renkema, 1981). In order to secure the supply of fresh produce DWIC allowed the enslaved to cultivate small patches of land on the least favourable sloped terrains. These so called slave gardens, provision grounds, *tuinen* or *kostgrondjes* (in Dutch language) played an important role in the agricultural sector in the Caribbean region (Berleant-Schiller & Pulsipher 1986, Briana & Kimberly 2017; Gill 2008; Pulsipher 1990). According to a 1721 government report there were a large amount of "negerstuijnen" on the island (Renkema, 1981). The enslaved were allowed to sell their produce on the local market, but also traded their produce with other islands in the region. There are strong indications that the enslaved labourers (and after emancipation Afro-Caribbean small holder farmers) developed and managed their own micro water cathment systems on the sloping terrains (Henriquez 1962; Renkema 1981; Van Keulen 2017; Pulsipher & Goodwin 1982a/b). When the first private plantations were established there were often conflicts between landowners about illegal confiscations of the public watering places or so called public *compagnieputten* as water was a scarce and valuable commodity.

Throughout the Dutch rule agriculture remained on subsistence level and land clearings and deforestation continued. Most notably for the export of the red dyewoods Stockvishout and Logwood throughout the 17th and 18th century. Meanwhile clearing of more land took place for (failed) experiments with sugar, cotton and indigo. Mangrove forest were cleared to use the wood for the construction of buildings. The grazing of cattle caused further soil erosion and prevented regrowth of quality green cover. In 1952 Westerman even argues that there are no real 'forests' left on the island only woody areas of inferior quality (Westerman, 1952). Chopping of firewood for cooking and other domestic chores also must have had an important impact on the reduction of woody green cover (Verstappen, 2020). Upon the instigation of the government, to stimulate innovations in the ailing the agricultural sector, the last large land clearings were carried out in the 20th century to establish aloe vera and sisal culture. The introduction of wind powered wells around 1880 allowed for a short-lived modest boom in the cultivation of a local species of lime tree used in a liquer. The wind powered wells not only supplied agricultural irrigation systems with steady amounts of water for the orchard but were also beneficial for the operation of the so called commercially operated *waterplantages* (water plantations). The *waterplantages* supplied urban residents, cargo ships, businesses, governing bodies and army of water up until the introduction of the first water desalination plants in the slipstream of the oil boom in the 1920's.

Part 3 of this paper describes the development of water management system and typologies in more detail.

FIG. 2 Detail of 1730 map of the island of Curaçao. Clearly indicated are the "water plaats" (watering place) and "Ronde put of kuil daar men vers water haalt" (round well or hole where people get their water). Maker: Gerard Van Keulen. Source: Leiden University.

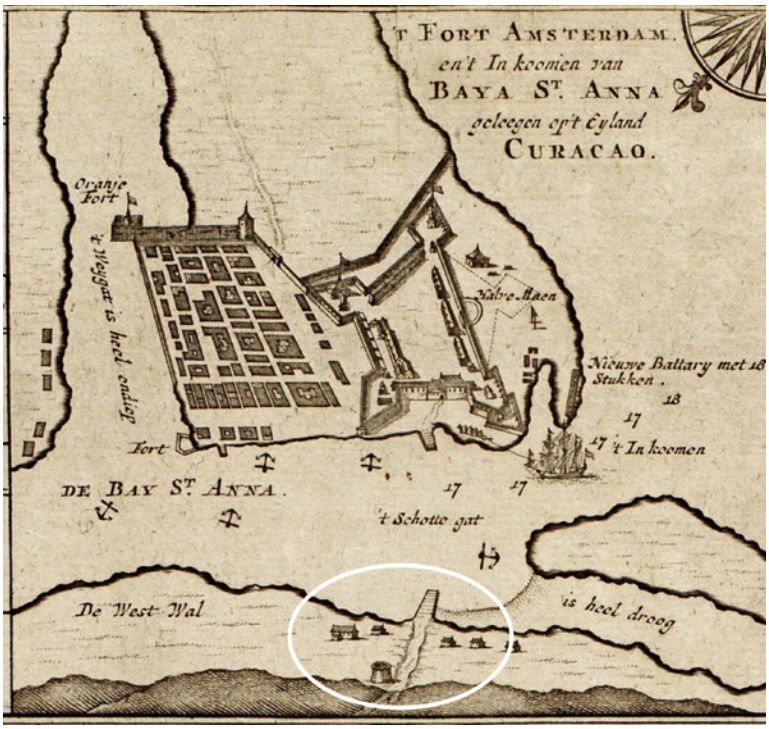

FIG. 3 Detail of 1730 Map of the island of Curaçao. On the foreground of Fort Amsterdam a well is depicted. Maker: Gerard Van Keulen. Source: Leiden University.

3.3 WATER MANAGEMENT STRATEGIES, WATER ELEMENTS AND TYPOLOGIES OF CURAÇAO

1 *Bronnen* (natural springs, seeps)

Prior to the Spanish occupation of the Island the native Amerindian community was around 2000 people large. Their first known settlement was at Rooi Rincon near the airport of Hato. Here water moving through the karst formation would have poured out from the rock formation below a natural overhanging cliff or notch (Haviser 1987; Hartog 1967; Versluys 1934). Enslaved people who fled captivity sought hiding in the caves making use of these water sources. Today water stills flows through the Hato caves. According to Versluys infiltrated rainwater moved too fast through the porous karst, eventually spilling out to sea at the foot of cliffs, and that therefore '*bronnen*' quickly ran dry. Versluys mentions the ancient hongerbronnen (hunger springs) used by the natives near plantage Hato. According to Versluys the quality of the water from these springs was low. According to Eeuwens (1934) upon seizing control from the Spanish in 1634 over the island the Dutch discovered the abandoned settlement at Hato. Here the DWIC established Plantage Hato, the first plantation or so called *compagnietuin* for the provisions of food and water for its people, founded on prior native and Spanish settlements with ready access to fresh water (Renkema, 1981; Eeuwens 1934). Sold in 1796 by the DWIC it was also the last plantation the DWIC managed themselves (Renkema, 1981). The grounds of Hato were pre-dominantly in use as *kostgrondjes* (slave gardens / provision grounds) by the enslaved labourers who, throughout the Dutch Caribbean, were allowed to sell their harvest at the local market in an attempt to ensure local fresh food provisions (Pulsipher, 1990). The garden of the Hato manor house, in use as country residence by the DWIC

director and later governor of the island, was furnished with a pond (Versluys 1934). Monumentzorg Curaçao describes a *regenbak* (rainwater cistern) next to the manor house, with overflows to a terrace, probably the pond, and also the *hof* with *putten* (wells), terraces, kanalen (gutters) and "other constructions" for an irrigation system (Curaçaomonuments, 2020a). The irrigationsystem in the *hof* was supplied with *putwater*. Interestingly the garden of the governor's house of St. Eustatius also boasted a pond (Van Keulen, 2017). According to Van Keulen the pond was, in a region were water was a valuable and scarce good water, an important status symbol and an indication of wealth. Hato is an interesting example of how native water sources and settlements were occupied, transformed and adjusted to meet the practical needs and architectural style of the colonial power.

On map fig. 4 Plantage Hato is named "Landhuis Hato". Here "*bronnen*" and "*waterbassins*" are indicated. These open *waterbassins* refer to the terraces described by Monumentenzorg Curaçao. In his description of the waterplantage economy Renkema argues that rainwater was more sought after then '*putwater*' (Renkema 1981). Versluys also states the inferior quality of brackish springwater from the karst near the coast. Water obtained from *bronnen* on higher altitudes was less brackish and of better quality.

Although Werbata does not provide an individual symbol for '*bron*' in his legend on map C.08 he indicates a '*bron*' (fig.9) surrounded by an earthen dam or *faha* on plantage Poos di Wanga located on the foot of a hill just north-east of plantation Hato. In the local Papiamentu language *faha* is translated as girdle. As many words in Papiamentu are of native Caribbean origin, this could also be the case with *faha*. According to Hartog (1968) the use of shallow *karstbronnen* or karst wells was well developed upon arrival of the Dutch. Although there is little known about Precolumbian (Arawak & Caquetio) water management systems on the Lesser Antilles I think it is highly probable that the native Caribs would have developed micro water catchment systems such as *faha* to secure water supply by storing and harvesting and saving it from running into sea. From 1499 until 1515 the Spanish observed and took over Caquetio agriculture practices (Hartog, 1961). As water was equally if not more important the Spanish must have observed where and how the native Caribs obtained and managed fresh water. The Spanish deported almost the whole natives Caribbean population to the cash crop plantations of Hispaniola in 1515 to work as enslaved labourers. When the Dutch took control over the island in 1634 the Caquetio population had grown and outnumbered the Spanish. Upon seizing control over the island the WIC also took control of it's settlements and subsequently it's water resources (Eeuwens, 1934). Soon the DWIC granted the Caquetio free passage to Venezuela with their Spanish lords. Only 75 Caquetio were believed to have remained on the island to secure food supply (Hartog, 1968) and most probably also to secure water supply. According to Debrot (2009) the influence and legacy of the native Caquetio has been often underestimated while archeological findings and early eye witness reports support his hypothesis that their legacy and influence was much more lasting and profound.

FIG. 4 Landhuis Hato with surrounding tanki water elements. At Landhuis Hato waterbassins and springs are indicated. Detail map C.09. Maker: Werbata-Jonckheer. Source: authors own.

2 *Karstputten* (karst wells)

According to Hartog (1968) the use of shallow *karstbronnen* or karst wells (fig.5; fig.6) was well developed upon arrival of the Dutch. Debrot (2009) also refers to them as shallow water holes. Water moving through to karst is recharged by surface and point infiltration in the naturally occurring holes, pits and cracks in the surface. During periods with significant rainfall these cracks and pots, the *karstputten*, would fill up and sometimes even spill over forming water pools. During droughts the pits and pools would run dry quickly. According to Versluys (1934) the quality of karst water on higher altitude at a distance from the coast is less brackish and of better quality. As mentioned before with the *bronnen* it is highly probable the Caquetio built dams or walls around these pits to prevent water loss from overflowing *karstputten*.

Probably a number of these water sources used by the Caquetio people were later used and/or controlled by the Spanish and the following Dutch rulers and landowners. See typology waterput or *plantageput*. Werbata uses the term "waterput" and "*bron*" on his maps. It is not clear if he is referring to naturally occurring *karstputten*, manmade wells or both. Since *karstputten* were also transformed or adapted to their use as *plantageputten*

FIG. 5 Karstput at the Noordkant. Photographer: Mary van Soest. Source: MOWIC)

FIG. 6 *Bron* (spring) with a stone wall at Roi Rincon. Photographer: Mary van Soest. Source: MOWIC

3 *Rooi*

According to Werbata's legend (fig. 1 nr. 6). a *rooi* is a "in the rain season filled dry bed of a brook". During rain runoff water flows downhill through the bed of the *rooi*. Some *rooi* are also fed with seepwater that flows out at the foot off porous karst formation hills, cliffs and notches. The *rooien* played an important part in the islands water catchment system. Werbata's legend shows a tanki (water reservoir) with *faha* on the course of a *rooi*. Veenenbos describes the local practice of planting fruit trees at the end of the course of a *rooi* (Veenenbos, 1955). This is a type of micro catchment and water soil storage in the rootzone that prevents soil deterioration (Boers, 1994).

4 *Pos di pia / waterkuilen – faha* system (small water holes and dam system)

Debrot (2009) refers to shallow hand dug water holes or *pos di pia*, a native Carib practice. Local resident Mary van Soest made an inventory of water supply related heritage. Soest describes a "sunken water hole" called Pos di orashon in Papiamento, which translates as 'source for prayer. Local people believe it was used by the native Caribs. It is possible that *waterkuilen* are either seasonally overflowing *karstputten*, sinkholes or dolines (geological terms), rainfed natural depressions (transformed by man) and/or manmade pools. The *waterkuilen* are fed directly and via runoff in brooks and streams (rooien) and via dams. *Waterkuilen / pos di pia* are usually located in forested terrain. However Breemen describes how small holder African Caribbean farmers dig out small circular area and built a stone wall around it on their *kostgrondjes*. In the middle they dig out a well from which they obtain water (Breemen, 1934). Breemen however does not describe how these holes are recharged with water.

FIG. 7 Girls in the hof (garden) of boarding school Welgelegen posing in front of a tanki with earthen dams. Photographer: Soublette et Fils. Source: RCE.

According to Breemen (1934) when large pools or *tanki* on the estate grounds fill up with rainwater the farmers quickly start sowing the moist slopes of the pool in circles around it. The difference between a *waterkuil* and *tanki* (fig. 7) is not clear. It seems they both refer to pits or pools either manmade or natural depressions transformed by men. Werbata only uses the term *tanki* or *reservoir*. According to Renkema there were two types of dam systems in use. A small dam system and the large dam system. The small dam system could be found primarily on the *domeingronden* or unfavourable grounds of plantations with irregular and steeper terrain (Renkema 1981). As mentioned before during slavery these *kostgrondjes* were in use by the enslaved as kitchengarden. After 1863 the African-Caribbean community continued this practice as subsistence / small holder farmers. Renkema describes "many small dams as no higher than a few decimetres to maximum 1 meter" constructed "on the slopes and in small rooien". Henriquez (1962) describes the system in the Schottegat area (fig. 8). The small earthen dams are called *faha* (girdle in Papiamento) suggesting that they have a circular shape. Werbata's legend shows a *tanki* with a circular *faha* on the course of a *rooi* (fig. 1). Explicitly connecting

the three elements of the system. The large dam system was actually the same system but applied and magnified on the privately owned plantation grounds in the valleys. The Dutch socialist member of parliament Henri van Kol made rather patronising remarks in his report regarding how the African-Caribbean small holder farmers built their 'crippled terraces' on the steep terrains he observed during his fieldtrip in 1904 (Renkema, 1981). However according to Renkema the government considered the small *waterkuilen-faha* system (a micro water catchment system) to be more effective than the large *tanki-dam* system to raise the groundwater table. Governor De Jong van Beek en Donk promoted the use and renovation of this system in an attempt to help improve the ailing agricultural sector (Renkema, 1981). Boers (1994) refers to these types of rainwater harvesting as micro-catchment systems as highly beneficial and effective for land reclamation and soil improvement in arid and semi-arid regions. Pulsipher & Goodwin (1982; 2001) on Montserrat and Van Keulen (2017) on St. Eustatius both describe similar small water catchment systems on the more irregular and steeper terrains, outside the formal plantation fields in the valleys, consisting of small dams and man dug water holes. Both Van Keulen and Pulsipher & Goodwin mention that these systems are no longer in use and that locals are unable to tell them who built and managed these systems. Pulsipher & Goodwin argue they were designed, built and managed by the African-Caribbean people during slavery and some time after emancipation. According to Renkema the *waterkuil-faha* system was found in disrepair after emancipation of the enslaved (Renkema, 1981). In spite of government funding the planters were not enthusiastic to adapt to the micro catchment *waterkuil-faha* system. According to Do Rego owners of large estates resisted against the reforms of Governor de Jong van Beek en Donk (Do Rego, 2012). According to Renkema the planters preferred the larger *tanki-dam* system. Perhaps the planters lacked know-how and/or was it too expensive for the planters to pay the former enslaved labourers after emancipation to manage the micro catchment *waterkuil-faha* system as Pulsipher and Goodwin suggest in the case of Montserrat Pulsipher & Goodwin (1982; 2001). According to Do Rego the reforms to stimulate the micro catchment *waterkuil-faha* system turned out to be beneficial for the African-Caribbean community to improve and develop their small holder farms (Do Rego, 2012). I believe it is very well possible this micro catchment system and practices could have been appropriated from the native Caribbeans and passed on to the enslaved African-Caribbean to manage their *kostgrondjes*.

FIG. 8 According to Henriquez (1962) this area north of Schottegat was known for its small holder farmers and their small dam system. It fell victim to urban development due to the oil boom. Detail of map C12. Maker: Werbata – Jonckheer. Source: authors own.

5 *Tanki* (man made pool) - *dams*

According to Werbata's definition a *tanki* is "dug reservoir for rainwater". Werbata's legend shows a *tanki* with a circular *faha* on the course of a rooi. The use of the word *tanki* is interesting. In arid and semi-arid regions of India and Iran *tanka* or *tank* systems for rainwaterharvesting are well known (Pangare & Pangare, 2016). How and when the word *tanki* came into use, is not known. From 1807-1816 the English governed the island. It is possible they introduced the word *tanki*[2]. As mentioned before the *tanki* were fed by rainfall and runoff from the catchment area and consisted of a system of large stone dams, rooien and gutters directing water to the catchment pools: the *tanki*. This large dam system was based on the micro catchment *waterkuil-faha* system but adjusted and enlarged at the discretion of the landlords on their privately-owned plantation grounds in the valleys (Renkema, 1981). The 19th century Dutch traveller and writer Marten Douwes Teenstra was unimpressed with this large dam system. He noted in his observations published in 1836 that the construction of the dams was much too steep and easily collapsed during rain (Teenstra, 1836 in Renkema, 1981). According to Breemen (1934) when large pools or *tanki* on the estate grounds fill up with rainwater the farmers quickly started sowing the moist slopes of the pool in circles around it. On the fringes of the pool and on the foot of the dams beans, melons and other fruits were cultivated. As water would evaporate seeds were sown on the receding slopes untill eventually the whole pond was in use as a gardenplot. Sometimes the dam catchment system made use of natural depressions without digging out a significant hole. Fig. 11 shows a dam with a gentle slope on the water retaining side on Bonaire. Tanki served not only agricultural but also domestic activities. On Fig. 7 girls of boardingschool Welgelegen just west of Willemstad on the shore of Schottengat are posing in front of a *tanki* or *waterkuil*. Werbata indicated three *putten* and two *faha* on the premises of Welgelegen and the neighbouring orphanage. The maps indicated many wells and/or small *tanki* in the area on the foot of Seroe Jan Kok (seroe translates as hill in Papiamento) (Fig. 9). As mentioned before, in spite of government funding the planters were not enthusiastic to adapt to the micro catchment *waterkuil-faha* system. According to Do Rego owners of large estates resisted against the reforms of Governor de Jong van Beek en Donk (Do Rego, 2012). According to Renkema the planters preferred the larger *tanki-dam* system (Fig. 10). But still the planters had to water their crops by hand. With the introduction of wind-powered wells around 1890 in the Dutch overseas territories (30 years earlier than in the introduction in the Netherlands) a lot changed in the eve before the oil boom.

FIG. 9 The detail of map C.08 shows a series of tanki on the foot of hill Seroe Jan Kok. On a premises called 'Poos di Wanga a '*bron*' is indicated (poos or pos is Papiamentu for source or well). Maker: Werbata-Jonckheer. Source: authors own.

FIG. 10 The detail of map C.05 shows the large dam system near the manor houses with waterplantages North-east of Willemstad with rooien leading to water reservoirs on the sandy boca (outlets) to the sea. The small dam systems are located on the higher sloped terrain west of the manor houses where possibly the kostgrondjes of the Afrocan Caribbean small holder farmers. Maker: Werbata-Jonckheer.
Source: authors own.

FIG. 11 Valley in Bonaire with large dam structure on the foot of a. Photographer: Boy Lawson. Source: Het Geheugen van Nederland.

6 *Putten* (dug wells)

According to Versluys (1934), upon arriving on the island, the DWIC immediately started digging wells. According to Versluys with little success. So called *putwater* was of pour quality while rainwater was preferred for human consumption. *Regenbakken* were constructed to supply the troops and other DWIC workers with water. They were constructed on the forts and manor houses but water was always scarce. As the DWIC was also responsible for the public water supply it oversaw several *compagnieputten* on compagnie grounds where all residents were free to water their cattle (Renkema, 1981). According to Versluys (1934) and Curaçaomonuments (2020c) the *voetput, pos di pi, pos di trapi* and/or *belopen put* (foot well or stair well) at Fort Nassau is the oldest type of dug well of the island. The *voetput* is a rectangular shaped reservoir or well and has 3 straight walls and one sloping ramp or stairs leading into the well. Rather confusingly terms for water elements like *waterkuilen* and *pos di pia* are used for both water holes, karst wells and man made wells. For these types of rectangular wells I will not use the word *pos di pia* but rather *pos di trapi* and *voetput* used for watering cattle and land. Governor Raders who tried to push innovation and reforms on the island during his tenure from 1836-1845, introduced noria's (waterwheels) against the objections of the locals as they knew that water levels in wells were hardly predictable. The wells were either dry or overflowing. The use of noria's never gained any following (Renkema, 1981). As soon as the planters of privately managed plantations started farming their lands from 1660, emphatically invited by the DWIC to the island to help keep up fresh food supply, conflicts emerged around these *compagnieputten*. Next to taking control over and digging wells and *tanki* on their private lands the planters immediately confiscated the land around the *compagnieputten*, claiming the land and taking control over these water sources (Renkema, 1981). Land and water disputes were often legalised by allowing landowners to buy the land. *Compagnieputten* then became *plantageputten*.

— *Pos di trapi / voetputten.*
Earliest type of wells built by the DWIC (Versluys, 1934). An example of a *voetput* can be found on the foot of a hill of Fort Nassau (1796-1797) (fig. 12). On map CWO Werbata indicated the voetput as waterreservoir.

FIG. 12 Photo of pos di trapi at Fort Nassau (1796-1797).
Source: Curaçao.com.

— *Compagnieputten*
As mentioned before under *bronnen* it is likely these wells were established on shallow wells or water holes used by the Spanish and /or native Caribbean (Debrot, 2009). A most famous dispute occurred around Zuurzaksput in 1722 between several plantation owners. Neighbouring plantations accused the owner of plantation Savonet of illegally occupying the compagnieput of Zuurzaksput. A map drawn in 1723 by the DWIC mentions the disputed well in the "forest in question". As well as water sources also forests were often subject to dispute due to illegal occupation (Renkema, 2016). Fig. 13 shows the hand drawn well Zuurzaksput in 1905 (Gravenhorst, 1905). The well is, typically for the typology of the plantation, situated in a *hof* surrounded by bush, fruit trees and kitchen gardens. Fig. 15 shows plantation Savonnet with wells and wind-powered mills.

— *Plantageputten* (plantation wells) & *Regenbakken* (rainwater cisterns)
Wells belonging to the property of the plantation where either dug wells constructed by the (enslaved) workers of the plantation, old dug wells, *bronnen*, *karstputten* of Spanish or native origin or *compagnieputten* adjusted to the convenience and needs of the plantation. They could be square or rectangular *voetputten*, or circular dug wells constructed in stone and/or on top of shallow karst wells. As mentioned under *compagnieputten* the *plantageputten* were located in the valley just below the foot of the hills where the manor house was located. According to Renkema (1981) the *plantageputten* in the *hof* were surrounded by fruittrees, the owners vegetable gardens and sometimes slave gardens and huts all conveniently located near this source of *putwater*. The manor house was located at the highest point on the foot of the seroe overlooking the *hof*, fields, *savanen* (grazing grounds) and kunuku (enslaved) labourers settlement. The slavegardens were usually located on higher unfavourable steep grounds or on neighbouring compagnie grounds. Rainwater was collected from the roofs of the manor house and other buildings and directed to waterbakken or regenbakken (rainwater cisterns). These *regenbakken* were located near the manor house, usually half below surface (fig. 17). The *regenbak* from plantage Hato supplied the garden pond on a terrace with rainwater via overflows (monuments, 2020a) The manor house of plantation San Juan is even

supplied with rainwater via an aqueduct architecturally integrated in the architecture of the complex (fig. 14). Monumentenzorg (monuments, 2020b) describes the complex as "A group of magasina's with cistern connected with an aqueduct to the main building". The enslaved labourers would have been restricted from use and/or subject to rationing of rainwater and/or *putwater* (Pulsipher & Goodwin, 1982; 2001) from their landowner. According to Pulsipher and Goodwin the enslaved therefor developed their own micro water catchment systems.

That water supply could be challenging also speaks volumes when Werbata indicates a "zeer diepe leege put" (very deep empty well) on map C.17

FIG. 13 Picture of the much disputed compagnieput and later plantageput Zuurzak in around 1900 in a grove surrounded by labourers or small holder farmers. The putten (wells) are always located in the grove with forest and/or fruit trees and near vegetable patches. Photographer: Soublette et Fils. Source: Gravenhorst, J., 1905.

FIG. 14 Photo of the manor house of Landhuis San Juan in 1954. The arched aqueduct on the right directs the rainwater from the roofs to the regenbak (cisterns). Photographer: Van der Wal. Source: RCE.

— *Windwaterputten* (wind powered wells)
According to Renkema American windmills were introduced around 1880 on (Renkema, 1981). Interestingly the introduction of the windmills on the overseas territory preceded the introduction in Netherlands by 20 years (Molendatabase, 2020). In the overseas territory of the Dutch Caribbean the windmills were applied to overcome water shortages by mining groundwater for irrigation and consumption. In the Netherlands the windmills were applied to manage surface water levels and drain excess of water from the low-lying polders. The sudden abundance of water the windmills provided made it possible to start growing oranges on the island. The owners of plantage Groot Kwartier and Joontje placed so many windmills in 1888 that it allowed them to water their cattle as well as an orchard boasting 400 oranges (Gravenhorst 1905; Renkema 1981). To store and support the constant flow of *putwater* closed and open stepped *waterbassins* or terraces were constructed (fig. 15). Cattle could directly drink from these bassins or water was channelled via gutters to cattle wateringplaces or the fields for irrigation. This extensive system of wind powered wells, *waterbassins*, terraces, stone gutters and iron pipes was only viable if the groundwater was sufficiently replenished with *zakwater* (infiltrated rainwater). Which was not always the case.
The *windmotoren* also made work easier for so called '*waterplantages*', plantation whose primary source of income was the selling of water (and salt) to the urban population, docking ships and army (Renkema, 1981). Throughout the Dutch Caribbean islands wind powered wells were (and sometimes still are) in use for private and public water provision (fig. 18).

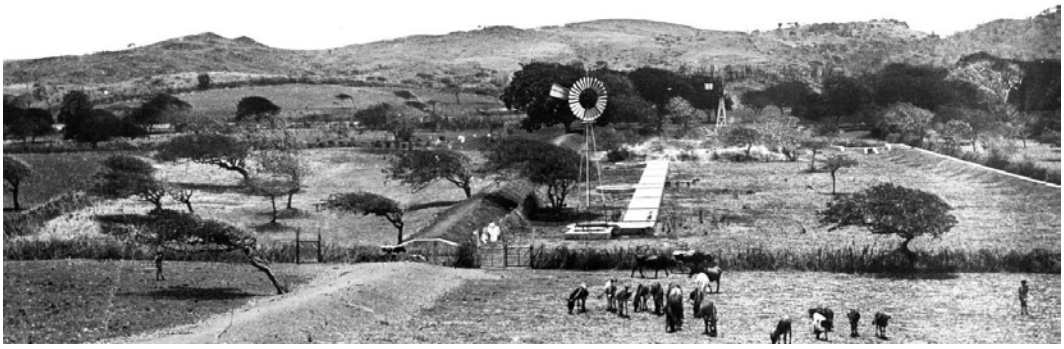

FIG. 15 Windwaterputten (wind-water-well) with series of water reservoirs in the valley of Plantation Savonet around 1900. Between the cattle and the water system a rooi is situated. Large earthen dams are built around the premises as water catchment system. In the hof divi divi trees are planted. Photographer: Soublette et Fils. Source: RCE.

— *Waterplantage* (water plantation)
The *waterplantages* are quite a remarkable and contradictory phenomenon on an island frequently suffering from severe droughts and water stress that could last for several years. Water selling by private landowners, to local residents, cargo ships, government and army, was however a common practice on the Islands of Lesser Antilles. In the Dutch Caribbean most notably on Curaçao and St. Eustatius who both experienced 'golden' years as regional and global trading posts (Van Keulen 2017; Espersen 2013; Renkema 1981). Renkema's study on the plantation economy of Curaçao revealed that plantations where, in terms of agricultural practices, actually small holder or subsistence enterprises. They pre-dominantly supplied food to the landowners, the enslaved labourers and the local and regional markets (Renkema 1981; Versluys 1934; Breemen 1934). These plantations had very little in common with plantations of the era that produced cash crops like sugar and cotton on a large scale for the global market. As mentioned before some plantations of relatively small size and/

or with little agricultural value and viability were taxed at surprisingly high rates due to their trade in so called '*putwater*' (well water) and sometimes also salt. As water was a scarce commodity for residents of Willemstad, where room and/or means to build *regenbakken* often lacked, water became a very highly valued good. For plantations located at comfortable distance from Willemstad the trade in freshwater was in fact the only commercial pillar of their enterprise. The introduction of American *windmotoren* or windmills around 1880 had profound impact on the volumes and speed with which water could be drawn from the ground. The lack of water was compensated with a secure supply of passaatwind allowing for a continues supply of *putwater* (Versluys, 1934). Before the introduction of these mills *waterplantages* often struggled to meet demand and failed to meet the quantity they were obliged to supply by contracts to their clients such as DWIC. According to Renkema the most prominent *waterplantages* were located near Willemstad around the shores of the Schottegat bay. Plantations De Hoop, Valentijn, Asiento and Groot Kwartier (with the orange orchards) were the most important *waterplantages*. *Putwater* drawn from the wells was stored in stepped *waterbassins* and via gutters and pipes channelled to the shore of the bay. There the water was loaded onto waterkanoes or waterboats and sailed to the clients. Plantage Asiento boasted 13 *windwaterputten*. Per day 100-ton water was drawn from four of these wells to supply the newly built oil refinery at Schottegat Bay in 1918. Before the introduction of windmills the *waterplantages* also directed runoff water to open waterreservoirs on the shores of the Schottegat. Werbata indicated several large waterreservoirs on *zandvelden* (sand fields). This practice was used to improve the water quality of these planes and to make them more suitable for agricultural purposes.

The islands oil boom changed everything on the island. The sudden wealth due to the availability of fossil fuel as energy source and skyrocketing water demand led to quick depletion of groundwater resources and the installation of one of the world's first desalination plants. Up until today, the region still relies heavily on desalination plants. Accoring to Verstappen (2020) the oil boom did have some unexpected benefits for the return of green cover of the island. Because of the sudden availability of petroleum inhabitants were no longer required to chop firewood for cooking. Also goat herding was abandoned in favour of work in the oil and service industries (Verstappen, 2020).

FIG. 16 This map shows the waterplantages around Schottegat bay. At Plantage Groot Kwartier an iron pipeline was constructed to direct water to the water reservoir on the shore of the bay. In 1911 Asiento only had three wind-powered wells. By 1918 there were 13 mills. Next to large earthen dams there are also soil storage waterreservoirs on the shore of the bay. In the east corner of this map there is a pumpingstation. Most probably for pumping water into cargo ships.

FIG. 17 Ruin of waterkelder/regenbak (cisterne) the benedenstad of Sint Eustatius. Relative high rainfall of 1200 mm (700-900 NL) turned Sint Eustatius into a strategic transshipment port in the Caribbean. Rainwater was 'harvested' and sold to cargoships. Today Bij gebrek aan adequate centrale watervoorziening worden bewoners in droge perioden geconfronteerd met drinkwater tekorten. Photographer: Saskia de Kock.
Source: RCE.

FIG. 18 Men fetching water at a wind-powered well in Bonaire in 1964. On Bonaire the historical water supply systems have been restored but problems with management have occurred (Bonaire.nu, 2019). Photographer: Boy Lawson.
Source: RCE.

4 CONCLUSIONS & DISCUSSION

4.1 WATER TYPOLOGIES AND WATER TERMINOLOGY

The Werbata-Jonckheer maps were drawn specifically to provide detailed information for the implementation of the micro water catchment *waterkuil-faha* system. The level of detail and information the maps provide on the field of topography, landscape structures and elements and water management was unprecedented (Van der Krogt, 2005). One difficulty are the inconsistencies in the terminology used in the legend and on the map. It is necessary to study what definitions Werbata used and which Jonckheer used. Werbata drew the first maps of Curaçao assisted by Jonckheer (Van der Krogt, 2005). Jonckheer drew the other islands maps building upon Werbata's method and knowledge. However Jonckheer was born and raised in Curaçao and perhaps had additional knowledge that led him to use slightly different legend and terminology for the other islands. A next step in this research project is to further develop a glossary on landscape and water elements to determine the terminology. This first overview also needs further development by studying the systems of the other Dutch Caribbean islands and those of the Lesser Antilles in general.

4.2 BIOGRAPHY OF NATIVE CARIBBEAN AND AFRICAN CARIBBEAN WATER MANAGEMENT SYSTEMS

This study highlights the lack of knowledge on Arawakan and Caquetio influence and legacy in water management systems (Debrot, 2009) in the Lesser Antilles. As Van Keulen (2017) and Pulsipher & Goodwin (1982; 2001) have argued before this is also the case with the lack of knowledge on the influence, development and legacy of African-Caribbean enslaved and small holder farmers on agricultural practices and water management systems. While local and regional (inter island) food supply was heavily dependent on the African-Caribbean enslaved labourers, and after emancipation, small holder farmers, and their work on the *kostgrondjes*, the topic is under researched. Though I would not say 'surprisingly under researched' as scientific research is still subject to the 'postcolonial gaze' (Beard, 2000). Related to race is also the subject of gender as knowledge on water management might have been passed through female lines in an economy where able young enslaved men were often sold or, after emancipation, left the islands in pursuit of study and work. Pangare & Pangare have addressed the gender issue in their work. Van Keulens and Pulsipher & Goodwin research to identify authorship of watersystems in the Lesser Antilles underscores the importance of field research and interviews with local people. Most likely local practices and knowledge is undocumented.

4.3 PUBLIC WORKS AND INSTITUTIONAL GAPS

Another aspect of the 'clashing' of cultures in overseas colonial territories in relation to water management and 'public works' have been addressed by Ravesteijn and Kop (2004). In their research on public works in the Dutch East-Indies (Indonesia) the authors argue 'institutional gaps' led to failure during implementation of 'improved' public works. Most notably on several dam and irrigation works. The authors argue the Dutch engineers and governing institutions had difficulty fully understanding the local physical water management systems and the socio-cultural management behind them, this however did not stop them from 'improving' them. The introduction

of noria's (waterwheels) by Raders is a telling example. Bhattacharyya (2014) has highlighted the problematic transfer of public goods to capitalist and/or colonial governing bodies and institutions and the loss that comes with it of social, cultural, economic, legal and spiritual ownership for indigenous communities.

4.4 OIL AND POST OIL PERIOD WATER MANAGEMENT

The Netherlands and the islands of the Dutch Caribbean were two worlds apart in terms of landscape, economy and water management systems. The Dutch water system was based on draining excess water while in the Dutch Caribbean water was scarce. This led to completely different development and innovations in the field of fresh water management and water supply systems. The early introduction of the American windmills is one example. The other example is the introduction of one of the worlds first desalination plants. The physical landscape Werbata documented on maps changed dramatically from 1918 when the region's first oil refinery opened for production. This research project focuses on decentralized water supply systems and stops with the introduction of centralized water supply system based on desalination technology. The spatial impact and water management of that time deserves attention.

4.5 WATER HERITAGE FOR THE FUTURE: SPATIAL MODELLING AND HERITAGE MANAGEMENT

The oil boom stopped the development and implementation of the small *waterkuil-faha* and large *tanki-dam* system on a large scale short. While landowners questioned the benefits and effectiveness of the micro catchment system (Renkema, 1981) in modern day science there is consensus that micro catchment and soil storage systems combined with woody plants and trees are beneficial in arid and semi-arid regions (Boers, 1984). It is also safe to say that large scale land clearing and deforestation between 1700-1950 must have had affected the hydrological cycle and induced drought (Derix, 2016). We can only speculate if and how the islands soil quality and water management would have benefitted from the implementation of these system and if it would have provoked reforestation. Therefor integrated spatial modelling, akin the method of "history integrated solutions" as proposed by Kosian and Van Lanen (2018; 2020) is needed. An integrated approach to spatial modelling, that also takes eco-system and heritage-system services into account, enables heritage experts, spatial planners and water resource experts and professionals to start a conversation on equal terms on the value of heritage assets, both tangible and intangible, for the development of resilient water management systems for the future.

Acknowledgment

This paper is an output of the science project Thirsty Cities. MOWIC and Mary van Soest allowed the use of photos of her extensive fieldwork on water supply related heritage. Her inventory provided invaluable additional information and imagery. Curaçao resident Harrie Verstappen provided me with insights and observations on landscape conservation and water management. I thank Debjani Bhattacharyya and Carola Hein for their interest in and feedback on this research.

References

Acevedo, M. S. & International Monetary Fund. (2016). Gone with the Wind: Estimating Hurricane and Climate Change Costs in the Caribbean. Washington, D.C. : International Monetary Fund

Allen, C. (2017). Landscapes and landforms of the Lesser Antilles (World geomorphological landscapes). Cham: Springer. doi:10.1007/978-3-319-55787-8

Bhattacharyya, D. (2014). Fictions of possession: Land, property and capital in colonial Calcutta c. 1820 to c. 1920. Ph. D. Emory University 2014

Beardsell, Peter, (2000). Europe and Latin America: Returning the Gaze. Manchester, UK: Manchester University Press.

Berleant-Schiller, R., & Pulsipher, L. M. (1986). Subsistence cultivation in the Caribbean. Dordrecht: Foris Publications.

Blouet, B. W., & Blouet, O. M. (2009). Latin america and the Caribbean : a systematic and regional survey (6th ed.). Wiley

Bobbink, I., Loen, S.,(2013). Water inSight: An exploration into landscape architectonic transformations of polder water. Delft, Netherlands : TU Delft, Architecture

Boers, T. M. (1997). Rainwater harvesting in arid and semi-arid zones. ILRI. Dutch Caribbean. Sustainability, 9, 8. Wageningen, The Netherlands : International Institute for Land Reclamation and Improvement

Bonaire.nu (2019), Verspilling en misbruik van putwater. Bonaire.nu, Accessed 7 August 2020, < https://bonaire.nu/2019/05/07/verspilling-en-misbruik-van-putwater/>

Brears, R. C. (2020). Developing the circular water economy. Place of publication not identified: PALGRAVE PIVOT.

Brears, R. C. (2020). Nature-based solutions to 21st century challenges. Abingdon, Oxon ; New York, NY : Routledge

Breemen, P. (1934). De kleine landbouw in Curaçao. In Gedenkboek Nederland-Curaçao 1634-1934. Amsterdam, Nederland: N.V. Drukkerij en Uitgeverij J.H. de Bussy

Briana N. Berkowitz, & Kimberly E. Medley. (January 01, 2017). Home Gardenscapes as Sustainable Landscape Management on St. Eustatius, Dutch Caribbean. Sustainability, 9, 8.

Cooley, H., Gleick, P. H., Wolff, G. H., & Pacific Institute for Studies in Development, Environment, and Security. (2006). Desalination, with a grain of salt: A California perspective. Oakland, Calif: Pacific Institute for Studies in Development, Environment and Security.

Curaçaomonuments, 2020a, Landhuis Hato. Accesed 7 augustus 2020, <http://www.curacaomonuments.org/more-information.php?geo_code=178001>

Curaçaomonuments, 2020b, Landhuis San Juan. Accesed 7 augustus 2020, http://www.curacaomonuments.org/more-information.php?geo_code=089002

Curaçaomonuments, 2020c, pos di trapi at Fort Nassau. Accesed 7 augustus 2020, <http://www.curacaomonuments.org/drov-information.php?geo_code=540305>

Da Cunha, (2019). The invention of rivers: Alexander's eye and Ganga's descent. Philadelphia, Pennsylvania : University of Pennsylvania Press

Day, Mick. (January 01, 2010). Challenges to Sustainability in the Caribbean Karst. Geologia Croatica, 63, 2, 149-154

Debrot, A. O., (2009). Cultural ties to the land in an arid plantation setting in Curacao. Report number: Final report submitted to Commission of the Island Territory of Curacao,; Nomination to UNESCO of a Cultural Landscape Affiliation: Carmabi Foundation, Unpublished Report

Derix, R., (2016). The history of resource exploitation in Aruba. Landscape series 2. Spatial Developments in the Aruban Landscape: A multidisciplinary GIS-based approach derived from geologic, historic, economic and housing information (retrieved online 5 august 2020) http://cbs.aw/wp/wp-content/uploads/2016/12/H2_LandscapeSeries_The_History_Of_Resource_Exploitation_In_Aruba_10-10-2016.pdf

Distefano, G. (2016) How Was Venice Built?. Venice, Italy: Supernova Edizioni

Eeuwens, P. (1934). CURAÇAO BIJ DE WISSELING DER EEUWEN EN DE KEERPUNTEN DER GESCHIEDENIS. In Gedenkboek Nederland-Curaçao 1634-1934. Amsterdam, Nederland: N.V. Drukkerij en Uitgeverij J.H. de Bussy

ENRIQUEZ, P. (1962). PROBLEMS RELATING TO HYDROLOGY, WATER CONSERVATION, EROSION CONTROL, REFORESTATION AND AGRICULTURE IN CURAÇAO. Nieuwe West-Indische Gids / New West Indian Guide, 42, 1-54. Retrieved February 6, 2020, from <www.jstor.org/stable/41849372>

Entymonline, (2020). Tank (n.). Accesed 7 august 2020 <https://www.etymonline.com/word/tank>

Espersen, R. (2013). Water Use at Palmetto Point and Middle Island, Saba, Dutch Caribbean: A Modeled Approach for Settlement Viability [online] International Journal of Historical Archaeology (2013). No 17, pp. 806-827

European Commission, (2015). Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities. (2015). (Brussel, BE: European Commission.)

Garmon, W. T., Allen, C. D., & Groom, K. M. (January 01, 2017). Geologic and Tectonic Background of the Lesser Antilles. In Allen, C. (2017). Landscapes and landforms of the Lesser Antilles (World geomorphological landscapes). Cham: Springer. doi:10.1007/978-3-319-55787-8

Genovese, L., and Porfyriou, H. (Eds), (2012), Water shapes, Strategie di valorizzazione del patrimonio culturale legato all'acqua, Roma: Palombi Editori

GFDRR, 2016. "The Small Island States Resilience Initiative (SISRI)" SISRI Knowledge Note No. 1. Small Island States Resilience Initiative. The World Bank and Global Facility for Disaster Reduction and Recovery (GFDRR). Washington DC.

Gill, R.G., (2008). The Architecture and planning of the twentieth century on Curacao, 3th ed., Curacao: Klein Bottelier

Gravenhorst, J., (1905) De landbouw en Veeteelt op Curacao, Neerlandia, 9de jaargang, 1905, nr. 7&8. pp. 132-139

Gysen, K. (9 nov 2018) Integration is the magic word, How can fortifications become a long-term, integrated solution for urban and environmental challenges? (retrieved online 6 augustus 2020) <http://www.efforts-europe.eu/wp-content/uploads/2018/12/GYSEN.pdf>

Hartog, J. (1961). History of the Netherlands Antilles. Oranjestad, Aruba: De Wit.

Hartog, J. (1968). History of the Netherlands Antilles: 3. Aruba: De Wit.
Jones, J., (2010), Water sustainability: A Global Perspective (pp. 330-338). London, Great Britain: Hodder Education UK
Kliot, N., (2010). Water sustainability on small tropical and subtropical islands. In J.A.A. Jones (Ed.), Water sustainability: A Global Perspective (pp. 330-338). London, Great Britain: Hodder Education UK
Kop, J., (2004). Drinkwatervoorziening, assainering en bandjirbescherming in stedelijke gebieden. In W. Ravesteijn, & J. Kops (Eds.), Bouwen in de Archipel (pp. 201-223). Zuthpen, Nederland: Walburg Pers
Kosian, M., Van Lanen, R. (2018). Without History no Climate Adaptation. The Importance of Historical-System Analyses in Changing Environments. A Case Study from the Netherlands. Proceedings of the 23rd International Conference on Cultural Heritage and New Technologies 2018. CHNT 23, 2018 (Vienna 2019).
Loen, S., (2019). Thirsty Cities: Learning from Dutch Water Supply Heritage. In C. Hein (Ed.), Adaptive Strategies for Water Heritage (pp. 79-105). Chaim, Switzerland: Springer Open
Ministry of Infrastructure and the Environment. (2016). National Climate Adaptation Strategy, The Hague, The Netherlands
Molendatabase, (2020). Herkules Windmotoren, accessed 7 August 2020. <https://www.molendatabase.net/detail.php?dbnr=699>
Oers, R. van., (2000). Dutch Town Planning Overseas during VOC and WIC Rule (1600-1800). Zutphen, Nederland: Walburg Pers
Pangare, V. and Pangare, G., (2015). Ancient Water Wisdom: Traditional water systems India. In Willem J.H. Willems & Henk P.J. van Schaik (Eds.), Water & Heritage: material, conceptual and spiritual connections (pp. 57-69). Leiden, Netherlands: Sidestone Press
Pangare, V., Pangare, G. and Das, B., (2006). Springs of Life: India's Water Resources. New Dehli, India: Academic Foundation
Pulsipher, L. M. (January 01, 1990). They have Saturdays and Sundays to feed themselves: Slave gardens in the Caribbean. Expedition (university of Pennsylvania. University Museum), 32, 2.
Pulsipher, L. M., & Goodwin, C. M. (2001). 'Getting the essence of it': Galways plantation, Montserrat, West Indies. Island Lives : Historical Archaeologies of the Caribbean, 165-203.Tuscaloosa: University of Alabama Press
Pulsipher, L. M., & Goodwin, C. M. (1982a). Galways, a Caribbean sugar plantation: A report on the 1981 field season. Knoxville: Dept. of Geography, University of Tennessee
Pulsipher, L. M., & Goodwin, C. M. (1982b). A sugar-boiling house at Galways: An Irish sugar plantation in Montserrat, West Indies. Post-medieval Archaeology, 21-27.
Ravesteijn, W., & Kop, J. (2004). Bouwen in de Archipel: Burgerlijke openbare werken in Nederlands-Indië 1800-2000. Zutphen: Walburg Pers.
Reh, W., Steenbergen, C. M., Aten, D., & Messchaert, W. (2005). Zee van land: De droogmakerij als atlas van de Hollandse landschapsarchitectuur. Wormer: Stichting Uitgeverij Noord-Holland.
Renkema, W. E. (1981). Het Curaçaose plantagebedrijf in de negentiende eeuw. Zutphen: De Walburg pers.
Renkema, W. (2016). Kaarten van de Nederlandse Antillen: Nederlandse Antillen tot 1900 (Ser. Explokart studies in the history of cartography, 15). Leiden: Brill, Hes & De Graaf.
Schmutz, P. P., Potter, A. E., & Arnold, M. E. (January 01, 2017). Aruba, Bonaire, and Curaçao. In Allen, C. (2017). Landscapes and landforms of the Lesser Antilles (World geomorphological landscapes). Cham: Springer. doi:10.1007/978-3-319-55787-8
United Nations, (1990), The Water resources of Latin America and the Caribbean: Planning, hazards, and pollution, Santiago Chile: United Nation, Economic United Nations, Economic Commission for Latin America and the Caribbean
Van Der Krogt, P., (2005). The Werbata Jonkheer Maps: The first topographic maps of the Netherlands Antilles, 1911-1915, Caert Thresoor, 24, 2005 nr. 1
Van Imhoff, E., Beets, G. A demographic history of the Indo-Dutch population, 1930–2001. Journal of Population Research 21, 47–72 (2004). https://doi.org/10.1007/BF03032210
Van Lanen. R. J., & Kosian, M. C. (July 12, 2020). What wetlands can teach us: reconstructing historical water-management systems and their present-day importance through GIScience. Water History.
Van Soest, J., (1977). Olie als water: De Curaçaose economie in de eerste helft van de twintigste eeuw. Zutphen: Walburg Pers.
Versluys, J., (1934). De Watervoorziening van Curaçao. In Gedenkboek Nederland-Curaçao 1634-1934. Amsterdam, Nederland: N.V. Drukkerij en Uitgeverij J.H. de Bussy
Verstappen, H., 2020 (personal account by Curaçao resident)
Westerman, J.H. (1952). Conservation in the Caribbean: a review of literature on the destruction of natural resources in the Caribbean area, with reference to the population problem. Utrecht, Amsterdam, Nederland: Natuurwetenschappelijke Studiekring voor Suriname en de Nederlandse Antillen
Zwart,. J., Bobbink, I., Aben, R., & Thijssen, E. (2004). Tussen haard en horizon: Landschapsarchitectonische bouwstenen. Amsterdam: SUN