The Cloud Gardeners
Water for a Thirsty Planet

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Extreme weather events, droughts, floods, shifts in precipitation and temperature patterns, melting glaciers, sea-level rise, water salinization, and more generally, changes in the water cycle remind us that the climate crisis is mostly a water crisis. Perhaps even more serious is a crisis of imagination connected with thought and with creative, far-sighted action able to combine the visionary and the pragmatic. A response to these two crises can be provided by the disciplines of landscape architecture: these have always featured a plural, collective approach that comprises or originates from living systems and natural forces, on the involvement of human and nonhuman communities in the design process, and the inclusion of the time variable in future plans—without neglecting the necessary flexibility of creative and pragmatic thinking. How can landscape design and different forms of collaboration open new doors to face climate and water challenges? What hopes can spring from collective design in its broader meaning?

This book sets out notions and ideas on water landscapes and (co)designed practices, identifying what hopeful routes might be taken for the three states of aqueous landscapes in transition—liquid, solid, and gas. The chapters show different scales and levels of design and collaborative practices: from large and governmental projects to small bottom-up interventions; from creative collaboration among designers to traditional community design; from participatory processes to nature as a co-designer for tackling the climate crisis. People, animals, plants, water, ice, fog, clouds, wind, sand, and rocks—all contribute to the cosmos' landscape symphony, and designing together can become a seed of hope to listen and embrace the Earth's climate changes.

Laura Cipriani is an assistant professor of landscape architecture at Delft University of Technology. Her current research addresses climate change issues, starting from the materiality of *water* and *soil*, and adopting (co)design approaches. Over the last decade, she has taught at Venice University IUAV, Politecnico di Milano, National University Singapore, Venice International University, and the University of Padua. She holds bachelor's and master's degrees in Architecture (Hons) from IUAV, a Master's in Design Studies (Hons) from Harvard Design School (2004), and a Ph.D. in Landscape Urbanism from IUAV. In 2008, Laura founded Superlandscape, a landscape and urban design firm.

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Aqueous Landscapes in Transition

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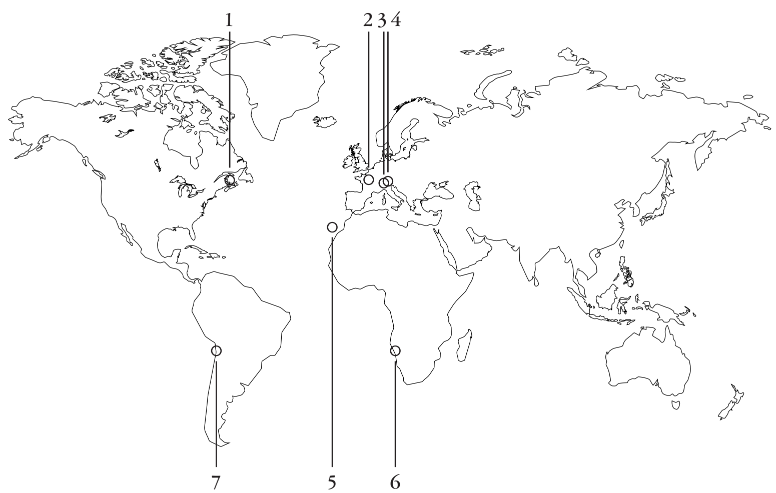
12 | The Cloud Gardeners

Water for a Thirsty Planet

Laura Cipriani and Gilles Clément



Design Project Data

1 | Fog x Beach
Location
Jamaica Pond | Boston | USA | North America
Coordinates
42° 19' 3.63" N | 71° 7' 13.082" O

2 | Fog Garden
Location
Chaumont-sur-Loire | France | Europe
Coordinates
47° 28' 41.336" N | 1° 11' 25.405" E

3 | Blur Building
Location
Yverdon-les-Bains | Switzerland | Europe
Coordinates
46° 46' 42.856" N | 6° 38' 27.296" E

4 | Nebolosus
Location
Zurich | Switzerland | Europe
Coordinates
47° 22' 0.897" N | 8° 32' 23.81" E

5 | La Geria
Location
Lanzarote | Canary Island | Spain | Europe
Coordinates
28° 59' 35.268" N | 13° 40' 9.07" W

6 | Namib Desert
Location
Namibia | Africa
Coordinates
24° 54' 34.212" S | 15° 19' 55.242" E

7 | Atacama Desert
Location
Chile | South America
Coordinates
24° 33' 22.69" S | 69° 25' 21.532" O

Some anthropic and natural practices involve working with the atmospheric phenomena of change of state, including clouds, fog, frost, and dew. This contribution explains how human and non-human 'cloud gardener' (Clément, 2021) practices can allow us to explore new (co)design techniques and open our imagination to new possibilities.
The introductory paragraphs 'Oceans of clouds. Drops of Fog,' 'The Rain Dance,' and 'Learning From Nature' by Laura Cipriani introduce readers to this theme by addressing the scientific-technical and poetic-aesthetic dualism of climate modification and adaptation by technologies, humans, plants, insects, bacteria, and microorganisms that oscillate between the two inverse phenomena of the passage of state: condensation and vaporization.
The last paragraph 'Clouds' is an excerpt from Clément's book *Nuages* (Clément, 2021) initially published in 2005. Clément explores clouds in the water cycle within the 'planetary garden' (Clément, 1999), intending to explain how cloud gardeners can 'create' and 'hold' water, frost, and fog in desert environments. From Chinese water towers to the Namib Desert, from the Atacama Desert to the everyday landscape of Clément in Limousin, France, cultivating clouds in dry regions of the planet also passes through the wisdom of gardeners who decide that their lawns should turn yellow. Letting plants organize with the new climate can provide hope in tackling the climate crisis.

Oceans of Clouds. Drops of Fog

Water is always unstable since it constantly moves in the water cycle. From the soil to the groundwater. From rivers to the ocean. From the sea to the atmosphere. Evaporation, transpiration, condensation, precipitation, infiltration, surface runoff, and subsurface flow are the physical processes of this constant movement. Today, climate change upsets water cycles and evaporation phenomena, increasing extreme weather events, droughts, and floods. Controlling the climate, or 'creating' rain, has always been considered a divine, non-human work. In many latitudes, the rain dance was a ceremonial rite to bring about precipitation while strengthening identity and social cohesion in the community (Merton, 1968; Chaves, 2010). The dance synthesized a (co)design of hope for an entire community to induce or 'cultivate' rain in certain areas of the planet.

This contribution describes working practices involving clouds, fog, frost, and dew. The intent is to talk about the gardeners of the clouds; that is, humans, animals, and plants capable of 'cultivating' water in conditions of scarcity and adapting to often extreme and inhospitable climates. Designing—or rather (co)designing—together with atmospheric phenomena is certainly not *the* solution for the changing climate. However, it allows us to open our imagination to new possibilities.

While we know that the global water balance at the planetary level remains essentially constant, the atmospheric phenomena of state change can fulfill temporary water needs. (Co)design through the condensation and vaporization of water—two inverse phenomena of the change of state—has given rise to a dualism of scientific-technical and aesthetic-poetic approaches to climate modification and adaptation by technologies, people, plants, insects, bacteria, and microorganisms.

The Rain Dance

Science has always tried to understand atmospheric mechanisms. Lamarck carried out the first scientific studies on clouds, which laid the foundations for modern meteorology in 1805 (Lamarck, 1805; Clemént, 2021). Using precise nomenclature, clouds are classified into 12 types based on their shape and altitude. Depending on their appearance, they are divided into isolated clouds with vertical development and extended clouds, elongated in layers. Based on their altitude in the sky, they are called *stratus* if closer to the ground or *cirrus* if further away. Even fog, composed of minute droplets of liquid water, is a ground-level cloud formed due to the condensation of water vapor in the atmosphere. It is precisely the phenomenon of condensation that involves a change in the state of matter from gaseous to liquid through heat removal.

From the middle of the previous century, technical sciences experimented with the possibility of interfering with clouds to encourage precipitation for

the first time. This so-called *cloud seeding* is tested through the dispersion of certain substances—including silver iodide, dry ice, or salt—using planes, cannons, or ground devices to induce precipitation from the clouds (Laaksonen and Malila, 2022). In the 1940s, the initial discoveries of Schaefer (1946) and Vonnegut (1947) gave rise to intense research on 'cloud seeding,' initially in the United States. There are many reasons for using such technology: to limit enemy attacks during war events, to make up for a shortage of water in a specific region, to prevent hail on crops, to limit air pollution in particular circumstances (fires and radioactive episodes), and to increase visibility at airports during foggy conditions. In China, the most recent and ambitious study conducted to understand the mechanisms underlying the phenomenon of precipitation on a global scale has produced a planetary map of what are called *sky rivers*: 'water vapor flowing in the sky rivers is the atmospheric water that is most likely to precipitate onto the earth's surface' (Wang et al, 2018). To these studies, we add the interest in climate manipulation, which, in China, has given rise to the Chinese National Weather Modification Development Plan 2014–2020, in which the potential areas of experimentation are defined (Hunchuck, Ferrari and Cheng, 2021). Although such technology remains in an experimental phase, being able to interfere with, design, and modify the climate opens worrying scenarios of climate geopolitics, if we can call it that.

On the one hand, the engineering sciences are developing techniques and technologies to induce precipitation. On the other hand, landscape design has mainly tried to interact with the atmospheric elements with ephemeral, poetic, and aesthetic purposes by referring to vaporization (i.e., the change of state from liquid to gaseous). There are numerous climatic fog and steam installations. Japanese artist Fujiko Nakaya has been designing fog sculptures in many gardens worldwide since the 1970s (Theurer, Lissoni and Duguet, 2023), and one of her latest creations stands next to Olmsted's Emerald Necklace. Artistic practices, architecture, and the art of gardens have given rise to various suggestions that, although fascinating and helpful in stimulating debate and the imagination, may be limited to the scenographic aspect of working with the vaporous state. Just think of the temporary garden in Chaumont-sur-Loire in France by Peter Latz (Latz+Partners, no date), the famous Diller Scofidio machine for the '2002 Swiss Expo' in Switzerland (Diller Scofidio+Renfro, no date), the recent Nebolosus installation by architects Authos and Stella Speziali in the ancient botanical garden of Zurich (Authos, no date), the surrealist illusions of Bernard Smilde (see Chapter 1), or the Cloudscapes by Transsolar and Tetsuo Kondo Architects at the Venice Biennale (see Chapter 14).

In some desert areas of the world, *cloud farming* based on traditional knowledge and centuries-old practices for water condensation has proven promising in interacting with the vaporous state to harvest water. Fog nets

Figure 12.1 | The semicircular lava craters of Lanzarote in the area called La Geria are a traditional hydro-geological system used to collect water for wine production. Photograph by iStock.com/Donhype.

Figure 12.2 | Aerial view of the semicircular lava craters of Lanzarote. Photograph by iStock.com/Hector Martinez.

such as those of Peter Trautwein or Arturo Vittori (see Chapter 1) have optimized and reinterpreted a traditional system called *atrapaniebla*, which exploits the condensation of water in fog in Peru and the Atacama Desert of Chile through a collection system. Such technological devices not only satisfy the water needs of small, isolated communities and activate local agriculture and reforestation in rural areas but also trigger the participation and involvement of local communities in such projects (Correggiari et al, 2017).

Similarly, the ancient wine-related agricultural practices in the lava landscape of Lanzarote in Spain in an area called La Geria involve an ingenious traditional hydro-geological system that continues to allow the production of wine grapes and other crops in a semi-desert climate even today. The lunar volcanic landscape combines the aesthetics of a gigantic land artwork with the skillful reuse of water condensation. In the myriad of semicircular craters lie vines protected from the wind thanks to dry stone walls and covered for a few meters by fragments of volcanic rock—the so-called *picón*. The layer of picón captures humidity, rain, and dew during the night, preventing evaporation and releasing it during the day, thus ensuring correct nourishment for the plant. These volcanic sandboxes emerged after the eruption of Timanfaya volcano in the mid-18th century and are essentially based on water condensation into dew to alleviate the lack of precipitation in the area. Dew is simply the deposition of water droplets that form on cold surfaces with temperatures lower than the dew point due to the condensation of water vapor in the air. Therefore, the picón layer has multiple characteristics: it is capable of capturing water directly from the environment since it has vacuoles that facilitate the passage of condensed water (dew); it prevents evaporation since the iron layer insulates the soil, preventing moisture from escaping through evaporation into the atmosphere; it acts as an insulating mattress for air temperature since it captures solar radiation during the day and does not dissipate heat from the ground during the night (Morales, Ojeda and Torres, 2015).

All these examples show how humans—communities, scientists, artists, and architects—have tried different ways to (co)design with the atmospheric phenomena of condensation and vaporization. A water dance to capture clouds, fog, frost, and dew in which plant and animal species also actively contribute.

Learning from Nature

In some areas of the planet, mainly where precipitation is rare, plants, insects, bacteria, and microorganisms use water from the vapor state as a vital source of hydration. The Namib and Atacama deserts are extraordinary examples for understanding the mechanisms of plant and animal adaptation to extreme environmental conditions since multiple species have evolved

to actively or passively collect water from fog or water vapor condensation (Gurera and Bhushan, 2020; Bhushan, 2020). This type of adaptation opens up new possibilities and potential experiments in times of climate change.

In the Namib Desert, a long and narrow coastal strip in southern West Africa, the unpredictable phenomenon of fog sustains the fauna and flora. Nearly 50 animal species use misty water in the liquid and vapor phases (Mitchell et al, 2020). Two species of beetles, *Onymacris unguicularis* and *Onymacris bicolor*, actively collect fog by basking in the mist (Hamilton and Seely, 1976) and capturing tiny droplets of water through the grooves of their carapace, finally conveying them to their mouths (Henschel and Seely, 2008). Other opportunistic species, although not active in collecting, drink the water from the fog deposited on vegetation or other surfaces. Moreover, beetles of the genus *Lepidochora* make structures to capture fog (Hamilton and Seely, 1976), while species such as *Onymacris unguicularis* emerge from their underground habitats to access misty water. To overcome unpredictable and episodic foggy events, some animals are even equipped with long-term internal water storage mechanisms.

Even plant species such as *Stipagrostis sabulicola*, a grass endemic to the central area of the Namib Desert, rely predominantly on fog for their water supply. The superficial structures of their leaves convey the collected water toward the base of the plant, allowing the efficient and rapid absorption of the atomized water by their superficial roots (Ebner, Miranda and Roth-Nebelsick, 2011; Roth-Nebelsick et al, 2012).

Even the Atacama Desert in Chile, one of the driest places on the planet, hosts multiple forms of plant and microbial life and is, by its nature, a laboratory for understanding the mechanisms of survival in extreme conditions. Although it was thought there was no life in such places, microorganisms have been found even in the most inhospitable areas. The fog advancing over the Chilean Coastal Range appears to be the main—if not the only—source of water for the microbial communities under the quartz of these hills (Azua-Bustos, Urrejola and Vicuñ, 2012). Although the minimum quantity of water necessary for microbial life in this environment and whether the microorganisms of the Atacama have evolved to be less dependent on water or have adapted remain unknown, it is evident that life persists with minimal quantities of water.

Desert plants also naturally evolved to thrive in arid, nutrient-poor conditions. Adaptive strategies common or specific to major Atacama plant lineages include the enrichment of bacteria that promote plant growth near their roots (Eshel et al, 2021). By sampling climate, soil, plants, and soil-microbial diversity, it is understood that associations between plants and microorganisms are essential for environmental survival. The soil close to the root system is enriched with bacteria that promote the plants' growth. Some cactus species, such as *Copiapoa haseltoniana*, native to the Atacama

Desert, use night fog as a supplementary source of water (Gurera and Bhushan, 2020). The epidermal surface collects fog and dew and is reflective when dry. The surface helps to increase water use efficiency by reducing the temperature difference between the plant and the air (Mooney, Gulmon and Weisser, 1977). Some cactus species are even equipped with conical spines with different integrated parts that serve various roles in the fog collection process depending on their surface structural characteristics (Ju et al, 2012).

To survive, plants exploit the humidity of the Pacific air, which is transported to the desert areas through fog. The Atacama Desert is also called a flowery desert since it transforms into a polychromatic and flourishing garden in peculiar and exceptional conditions. Under warmer temperature conditions due to El Niño currents, there is greater evaporation and increased precipitation in this area. When a few millimeters of rain and adequate temperature combine, they awaken seeds that have remained dormant for years. The desert is colored from lilac to an intense fuchsia thanks to a blanket of *pata de guanaco* (*Cistanthe sp.*) that covers the entire plain. With a progressive increase in rainfall, other blooms can be added: yellow and orange *añañucas* (*Zephyranthes bagnaldi*), white field *suspiros* (*Nolana baccata*), *malvilla* (*Cristaria sp.*) and *fraile coronilla* (*Encelia canescens*). It is a phenomenon as transient as it is poetic, which repeats itself with an unpredictable recurrence approximately every five to seven years and generates a complete ecosystem of insects, reptiles, and birds where even the fauna—which has also adapted to arid conditions—plays a crucial role in pollination and biodiversity. Desert plants arise from dormant seeds composed of an embryo, nourished by starch, and covered externally by a tough rind capable of spending five, seven, or even ten years in a latent state. In the last 40 years, about 15 events have occurred in the Atacama Desert.

The design of the landscape starts from a (co)design of different factors: plant and animal species have evolved to (co)design the landscape with fog and frost—so much so that the lessons of nature seem to surpass the ingenuity of humans in their beauty and wisdom. This is also the thesis Gilles Clément supports in the following chapter, taken from the book *Nuages* (Clément, 2021). The author explores clouds in the water cycle within what he calls the 'planetary garden' (Clément, 1999), which is the earth. Clément explains how cloud gardeners can 'create' and 'hold' water, frost, and fog in desert environments. Cultivating clouds in the dry regions of the planet also passes through the wisdom of the gardener, who lets plants organize with the new climate. The self-determinacy of plants provides hope in tackling the climate crisis. The human gardener can step aside and marvel at Mother Nature's gardeners' wisdom and renewing power.

Figure 12.3 | In the Namib Desert, the unpredictable phenomenon of fog allows the life of fauna and flora. Photograph by iStock.com/2630ben.

Figure 12.4 | The flowery desert of the Atacama manifests when a few millimeters of rain and adequate temperature combine. Photograph by iStock.com/Abriendomundo.

Clouds

Cloud: An aggregate of suspended microdroplets. Droplets are the result of condensation around a particle. Without particles—without 'impurities'—condensation does not occur. The particulate material covers a vast area, from waste dust to microorganisms. A cloud should not be considered water in vapor or dew but rather a complex, impure, and unformed whole.

The nature of the information enclosed in a cloud pertains to the nature of the impurities that make it exist. The wake of a jet aircraft is a cloud 'road' generated by the condensation of water vapor around kerosene particles. Transformed into rain, this cloud would be equivalent to an herbicide for a gardener. Other clouds loaded with nourishment act as fertilizer. A cloud combines the nutrients and the diluent necessary for assimilating that part of plants. We could feed a plant by making it pass through a cloud. The genus *Usnea*, 'beard lichen,' believed to live on the air of the time, feeds on tropical mists and low-lying clouds. Epiphytic plants care for every support: Tree branches, wires, electrical cables, pylons… A Usnea curtain, a wall of clouds, and the intimate meteorology of the bromeliads translate into an air saturated with water.

(…) A man jokes about the clouds, and the clouds protect him. Without them, the earth's temperature would be -18 °C on the ground, an ice desert. Their roof works like the glass of a gardener's greenhouse: Part of the solar radiation is trapped, maintaining an average temperature of 15 °C on the planet. This temperature depends on the natural composition of the atmosphere, in particular of the water vapor and future clouds. Gases such as CO2 (0.03% by volume) also minimally maintain the so-called greenhouse effect. Above all, the generalized concern about global warming comes from measurements revealing the real growth of this gas in the atmosphere and how this has contributed to an average temperature increase of 0.5 °C over the last century.

If the radiative balance remains balanced and livable for most species, the increase in temperature is accompanied by a series of climatic changes. Although all are known and analyzed according to more or less likely scenarios, they are always catastrophic for man.

(…) In certain countries, you have to go looking for (the clouds), interrupt their travel, modify their structure, and force them to turn into rain without bombing them, infiltrating them with poison, or altering the climate—without declaring war. Such gardening pertains to dry regions of the planet, where the weather conditions forbid all precipitation.

The Chinese have long cultivated clouds in cold deserts by building water traps as towers. The superimposed stones, neither grouted nor covered, form a massive concave building in the center. The humidity carried by night breezes passes through the building and condenses on the cold parts. Thus, the water drips on the sloping stones toward a well, where it collects. This

device captures the little water from low clouds, such as in Namibia and the Atacama Desert, where the collection is more considerable.

In these districts where it never rains, plants and animals live. They go looking for water or obtain it for themselves. In Moon Plain, located in the Namibian desert between Windhoek and the coast, lives a beautiful plant called *Welwitschia mirabilis* for this very reason. Two low-lying generative assemblies each develop a striped leaf that follows continuous growth without any vegetative arrest. The desert wind tears the only two leaves into more petite strips. The oryxes take shreds of it. At the armpit of a stump, which becomes woody over the years, the brown and silky cones of the male and female apparatuses emerge. The tangled whole suggests an abandoned job, an unfinished chignon, a pile, a 'mop' … The first botanist who identified and recognized the rare qualities of this endemic species of Namibia, capable of growing in a sterile environment and without water, is told that finding it incredible, he fell on his knees before it. The *Welwitschia* collects nocturnal water through a gutter process. The thick ribs, oriented toward the heart of the plant, channel the water on the seats. The plant can live for 2,000 years or more.

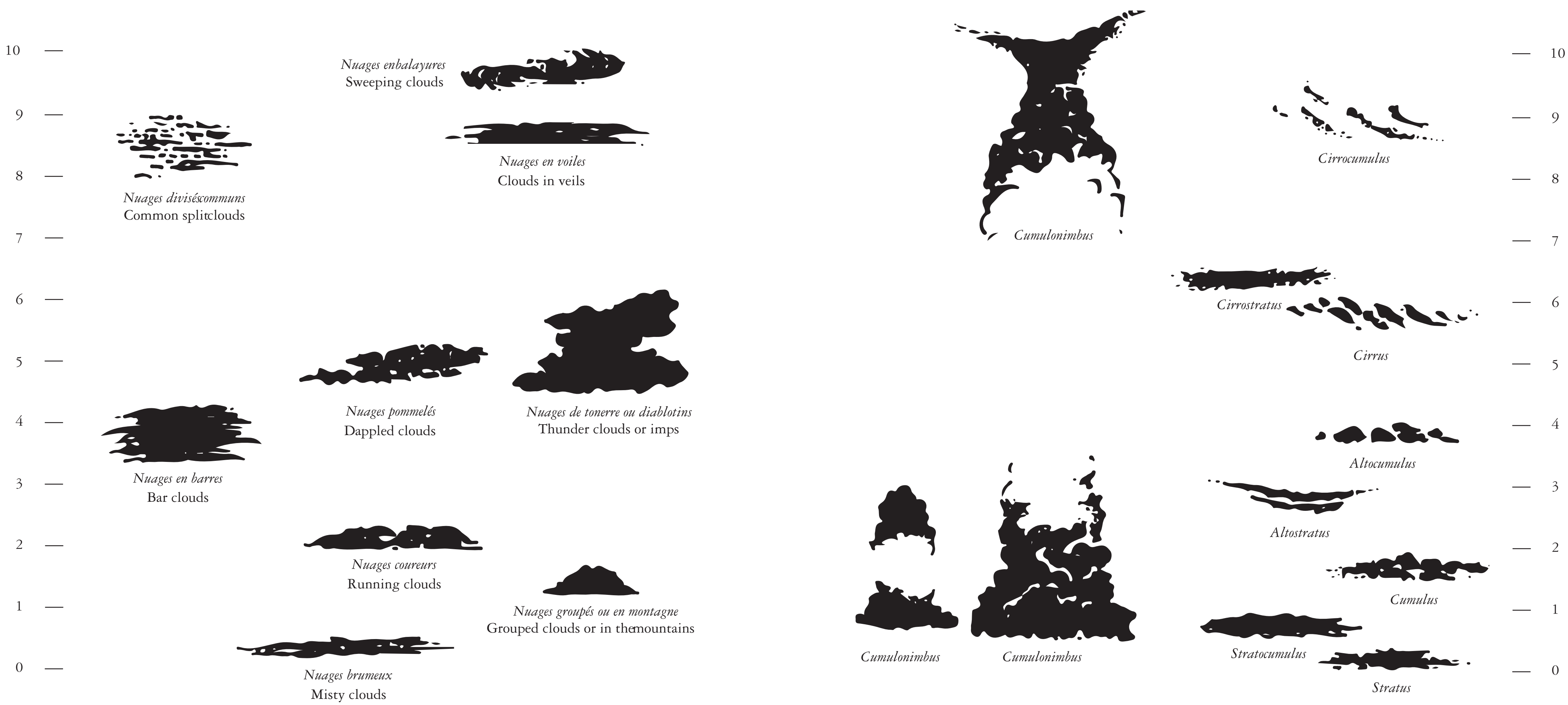
A giant black beetle that lives in the sand does the same thing. During the day, it is buried under the dune. In the evening, it climbs a ridge, positions itself against the wind, and straightens its abdomen. Water condenses on its carapace, flows into the gutters formed by the edges of the elytra, and heads toward the oral apparatus.

None of this would exist without the presence of water-laden clouds that circulate at night, vanishing in the morning in the heat of the desert. Namibia's water machine works in a close relationship with the nearby ocean. During the day, warm desert air blows toward the ocean, condensing above a sea cooled by the Benguela Current from Antarctica. This freshness is accentuated by an ascent of deep waters under the constant influence of winds and currents, which attract plankton and fish to the surface (upwelling). At night, the north wind from the sea pushes the clouds over the desert without turning them into rain. However, to take advantage of them, beings exist that are capable of capturing them.

The same phenomenon occurs along the Atacama Desert, from Chile to the Peruvian coast. The cold Humboldt Current heads north, curves, and 'drowns' toward the equator after washing through the Galapagos archipelago. The permanent upwelling only disappears in the presence of El Niño. The rest of the time, clouds or night mists similarly cross the desert from west to east. In Chile, these cloud formations collide with the relief of the Andes, where they manage to flow into some snow at high altitudes. Elsewhere, the desert remains dry. On the edge of this desert and cold ocean, the people of Chugungo have no water. The pipelines from the big cities have long since given way. The deserted village dies. Not far away, the pre-

Figure 12.5 | Clouds.
Photograph by Tom Barrett.

Figure 12.6 | On the left, cloud classification according to Lamarck (Lamarck, 1805). On the right, names and types of clouds in the troposphere. Image by Gilles Clement and edited by Laura Cipriani.



Andean hills welcome the coolness of the nocturnal clouds. Could they not be harnessed, forcing them to turn into the rain? Then, the engineers build a tightly meshed net to catch the water like fish. It is a fishing village. According to the principles of bionics, the plot is inspired by the structures of a canary tree. The tree 'rains,' while the dry region of the southern coasts where it lives never sees water. Its architecture and the imbrication of the leaves are such that they condense the humidity of the air. In Chugungo, the cloud gardener 'rakes' the condensed water on nets stretched up to seven meters high. Through curved gutters, the water is collected in large tanks. The village comes back to life, and the inhabitants return. You can even see flowers under the houses.

Every gardener—even those in regions where it rains—adapts to the clouds, supervises them, and doses his care according to the abundance or scarcity of meteors.

The first 'cloud' to come to our aid is the dew. It is not a formed cloud—with certain edges, as Lamarck would say—fat and limited to the upper regions of the troposphere. Although it is not a cloud at all, it works like one. Dew is produced as soon as the soil temperature drops to the point of starting the condensation of the water vapor contained in the layer of air with which it is in contact. To produce the same result, gardeners resort to a form of misting called 'sprinkler irrigation.' In Limousin, France, gardens are sprinkled with dew from mid-August. Barring exceptional heat, adding more water during the day is pointless. The absorption of water through the aerial tissues of the plant is just as necessary as that of the root tissues. The dew appears in the morning after a cool and clear night. Water droplets easily coalesce on ground obstacles as they bob in the air without settling. By raking the grass with a ladle, we can collect water like the gardeners of Atacama.

In general, plants 'get organized' with the climate. Massive watering, necessary for vases and other containers, has no reason to occur in the garden. The presence of species occurs in relation to the microclimatic sectors of the territory. The base of a tree is dry. Some species—periwinkles and cyclamen—resist this dryness. Wanting to put others that do not have the aptitude to tolerate this 'climate,' such as cyclamen or periwinkle—whatever their origin—forces artifice. Watering, watering, the programmer watering. Everything is underground, invisible, and effective. The tree, disturbed by this climate, rots and dies. Whether or not it falls on a house or the street during a storm depends on the butterfly effect of the moment. In an article entitled 'My dog was right,' Yves Delange stated how integrated watering, without criteria, has contributed to the disappearance of rare botanical species with heterogeneous needs. His dog did not like the hydraulic reel, an archaic and comical object that randomly distributes water.

While the pump irrigates, the gardener is occupied with other things. At this point, the question arises: Should the gardener care for something else? However, he must learn how much to distribute in one case and how much to limit himself in another. He is increasingly studying water distribution according to the species' needs. As in so-called precision agriculture, these montages require a sophisticated and expensive material to do roughly what nature does for us for free. In summer, you have to let the lawn turn yellow.

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