# Ecosystem-based Adaptation measures available in the Xiangtan Climate Resilient City Tool

The **Xiangtan Climate Resilient City Tool** developed by Deltares is a user-friendly urban resilience and adaptation planning support tool that facilitates collaborative spatial planning in priority areas for climate resilience improvement. Design participants can choose any of the 43 measures shown below and gain quantitative estimates of the resilience capacity improvement, co-benefits, and associated costs of the proposed adaptation measures in order to prepare an initial concept plan.

## Adding trees to streetscape

Pluvial flooding | Heatstress

Planting trees on streets, squares and car parks creates shade and evapotranspiration and therefore has a cooling effect. Dense foliage over busy roads is not beneficial, since the emissions from the vehicles tend to become trapped under the foliage. The type of tree should be chosen to suit the local moisture system.

## Bioswale (with drainage)

Pluvial flooding | Heatstress | Drought

A bioswale is a ditch with vegetation, a porous bottom and below that a layer of gravel, packed in geotextile with an infiltration pipe/drainpipe. It allows rainwater storage, infiltration and transport while helping to enhance biodiversity and quality of life.

## Cool building materials (high albedo)

Heatstress

The properties of surface materials concerning the power to reflect sunlight and the capacity to absorb heat influence the surface temperature. In general, light materials heat up less than dark materials. By choosing materials with less mass, such as wood and other porous materials that absorb less heat, the surface and the immediate surroundings will stay cooler.

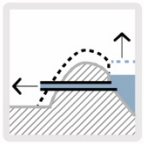
## Cooling with water elements - ponds

Pluvial flooding | Heatstress

A body of standing water, either natural or manmade, that is usually smaller than a lake. They may arise naturally in floodplains as part of a river system, or they may be somewhat isolated depressions. Usually they contain shallow water with marsh and aquatic plants and animals.

## Create extra surface water (sq.m)

Pluvial flooding | Heatstress | Drought



Realising additional surface area for storage can serve to create additional storage volume while the fluctuation in water level remains unchanged. Part of the standard fluctuation of 30 cm, for example, is then earmarked for seasonal storage, while the other part is reserved for peak storage. The advantage to this method of seasonal storage is that the fluctuations are limited, which is good for flora along the banks.

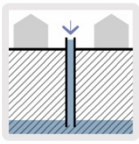
## Creating shadow

Heatstress

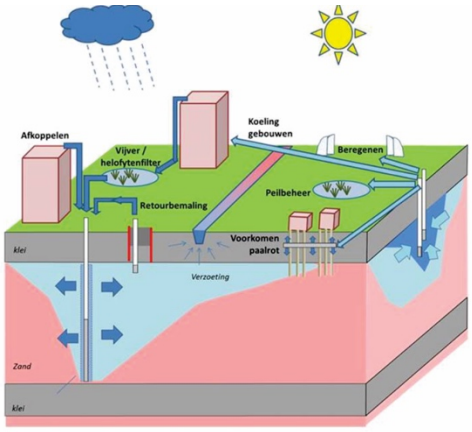
Creating shadow is important to prevent surfaces from heating up and to cool the surroundings. This can be accomplished by using trees, pergolas, overhangs, awnings and such. Arcades and covered walkways are urban elements commonly used in warm countries to create shade.

## Deep groundwater infiltration

Pluvial flooding | Drought

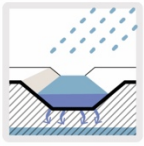


In many areas deep ground water aquifers are used as a source for drinking water. Groundwater infiltration is needed for sustainable use of these aquifers. If no water is infiltrated aquifers will be emptied. Deep groundwater infiltration is focussed on infiltration of water in deep aquifers. Rain water is collected and infiltrated in deep wells.



## Ditches

Pluvial flooding | Drought



A ditch is a small channel and facilitates temporary rainwater retention, transportation, and infiltration. A ditch can contain water or can stand dry. Ditches can be integrated into green verges or the roadside. They look natural but they do need extra space and maintenance.

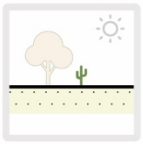
## Drainage-Infiltration-Transport (DIT) drains

Pluvial flooding | Drought

A sewage system using a perforated horizontal pipe wrapped with geotextile drains the ground, allows water to infiltrate and transports it. Such systems are used next to paved surfaces or next to unpaved surfaces that do not offer sufficient room for infiltration ditches or where the ground has an insufficient permeability factor.

## Drought resistant species

Heatstress | Drought



Drought-resistant plants are more suitable for bridging longer periods of drought, as they have a greater capacity to absorb water in urban areas and/or have a relatively low level of evaporation. The degree to which groundwater extraction occurs depends on the type of vegetation. In general a tree, for example, usually draws water from an area as large as three times the diameter of the crown.

## Extensive green roofs

Pluvial flooding | Heatstress

A green roof is a multi-layered roof system that is partially or entirely covered with vegetation. Extensive green roofs have a maximum depth of six (6) inches and are a layered system containing growing media, waterproofing membrane, drainage, and often irrigation components. Extensive green roofs can support groundcovers and shallow root plant material, and therefore require less structural support and reduced maintenance when compared to intensive green roofs.

## Floating puri-plants (floatlands)

Pluvial flooding | Heatstress | Drought

A floating wetland is a vegetated, artificial island typically used for small scale ecological intervention. These facilities are often used in canals and other surface waters to improve water quality. Floating wetlands also function as wildlife habitat.

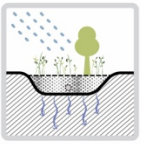
## Fountains, waterfalls, water facades

Heatstress

Standing water surfaces evaporate less water than green surfaces. Sprinkling water on surfaces serves to increase evaporation and lowers temperature. So moving water such as with fountains, waterfalls and water walls has a cooling effect on the surroundings. Surface water and rainwater can be used for this purpose.

## Gravel layers

Pluvial flooding | Drought



A gravel layer is a subsurface facility packed with gravel for infiltration of runoff. Runoff is carried above or below the surface and led into the layer or shaft. Such systems are used next to paved surfaces or next to unpaved surfaces that do not offer sufficient room for infiltration ditches or where the ground has an insufficient permeability factor.

## Green facades

Heatstress

Green facades attract and lose less heat. The plants also cause evaporation, which helps keeping the town or city's climate cooler. An advantage is that it takes up little space in an already intensively used urban area, while providing many vertical metres of green.

## Green roofs

Pluvial flooding | Heatstress

Green roofs' is a collective term used for walkable planted roofs and sloping planted roofs, and includes moss/sedum roofs and grass/herb roofs. Green roofs buffer rainwater up to a point. As they can become saturated, they are not suitable for buffering extreme precipitation. The roof itself, the underlying spaces, and the surroundings heat up less.

## Green roofs with drainage delay

Pluvial flooding | Heatstress

Green roofs with drainage delay are also called retention roofs. It is a green roof that can store extra water in a substrate layer under the green planted layer and is drained delayed with a pinched drain. A polder roof is a retention roof where the control system is linked to the weather forecast.

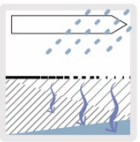
## Hollow roads

Pluvial flooding

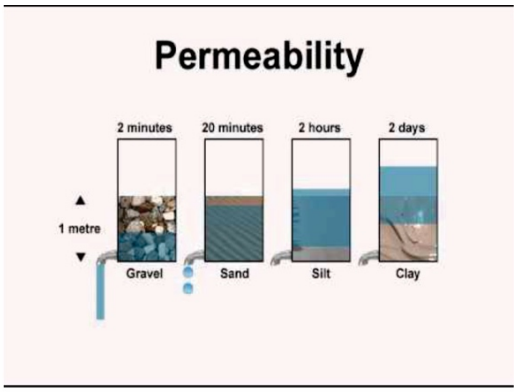
Hollow roads allow water on the road instead of only in a gutter and can hold and drain much more water than gutters. Slopes are often less of an obstacle for covering distances greater than 50 metres because the road level can be varied.

## Improve soil infiltration capacity

Pluvial flooding | Drought

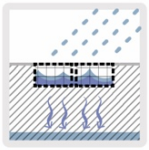


Amending soils improves the conductivity, or infiltration (in/hr) of the soil. This is achieved by increasing the permeability of the soil, allowing water to move through the spaces between soil particles more freely. Typically, native soils in the Greater New Orleans area consist primarily of compacted clays, which have small soil particles with little void space between. Replacing these clay soils with sandy soils, which exhibit large particles with a high void ratio, increases permeability.



## Infiltration boxes

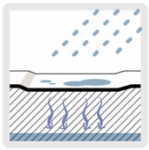
Pluvial flooding | Drought



Infiltration boxes buffer rainwater underground and allow using a single area for two purposes. In general they offer more storage capacity than above-ground infiltration installations. More rainwater can be buffered temporarily and gradually released into the groundwater. The extra infiltration leads to less drought damage, subsidence and salinization.

## Infiltration fields and strips with surface storage

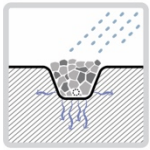
Pluvial flooding | Heatstress | Drought



Adding ditches or fields next to paved surfaces to temporarily store runoff is a simple way to allow water to infiltrate from clean hard surfaces such as roofs and cycle paths. Besides the volume of precipitation that needs buffering, the permeability of the ground is another factor that determines the dimensions.

## Infiltration trench

Pluvial flooding | Drought



An infiltration trench, also known as a French drain, is a linear feature used to reduce stormwater runoff and improve water quality. These shallow excavated trenches are filled with aggregate or crushed stone that is designed to allow for stormwater to infiltrate the ground plane and ultimately percolate though permeable soils into the groundwater. Their linear shape can also serve to convey stormwater from one area to another, or away from built structures, and typically contain a perforated pipe underdrain.

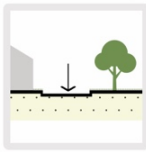
## Intensive green roof

Pluvial flooding | Heatstress

Intensive green roofs have a minimum depth of six (6) inches and are a layered system containing growing media, waterproofing membrane, drainage, and advanced irrigation components. Intensive green roofs can support groundcovers, bushes and even trees, and therefore require more structural support and maintenance when compared to extensive green roofs.

## Lowering of terrace

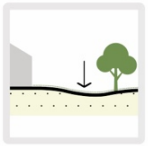
Pluvial flooding



Water from rainfall events can be temporarily stored on the terrace in a garden. By lowering the level of the terraces, more depth is available to retain precipitation and buffer the runoff, without the requirement of more surface area. The water is afterwards drained slowly.

## Lowering part of garden

Pluvial flooding | Heatstress | Drought



By lowering a part of the garden it is possible to create systems to capture rainfall, such as infiltration ponds, that store stormwater and allow rainwater to infiltrate. Besides buffering precipitation, this measure can also lead to a decrease of the air temperature.

## Permeable Pavement (storage)

Pluvial flooding | Drought

Permeable pavements consist of porous material that absorbs rainfall. Water can be stored either in the top layer (e.g. very open asphalt concrete) or in below the top layer in the foundation. Besides reducing runoff, permeable pavements can trap suspended solids and filter pollutants from the water.

## Permeable pavement systems (infiltration)

Pluvial flooding | Drought

Porous pavements consist of porous material through which water can pass; permeable pavements contain or create open parts through which water can infiltrate. These paving materials have several advantages: rainwater can be absorbed into the ground, replenishing the ground water and relieving the sewage system. Suitable materials are for example, open cell concrete blocks, grass concrete

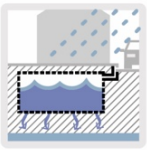
## Private green garden

Pluvial flooding | Heatstress | Drought

A residential or private domestic garden, is the most common form of garden and is in proximity to a residence, such as the 'front garden' or 'back garden'. The front garden may be a formal and semi-public space and so subject to the constraints of convention and local laws. Residential gardens are typically designed at human scale, as they are most often intended for private use.

## Rain barrel

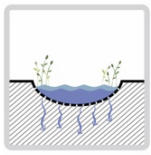
Pluvial flooding | Drought



Rainwater tanks are the simplest systems for homes, and the easiest to install. In most cases, the precipitation is used for irrigating plants: the tank is already located outside. Commonly used rainwater tanks are not overly large (a common size is 224 litres), meaning that they require an overflow if the roof surface to which they are connected is too large.

## Rainwater detention pond (wet pond)

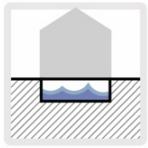
Pluvial flooding | Drought | Heatstress



Buffer ponds temporarily capture precipitation and allow it to drain off slowly. During rainfall, the rainwater is captured in the pond and subsequently drained off to create room for the next precipitation. Buffer ponds can be designed to have a mostly stony or a mostly natural appearance.

## Rainwater storage below buildings

Pluvial flooding | Drought

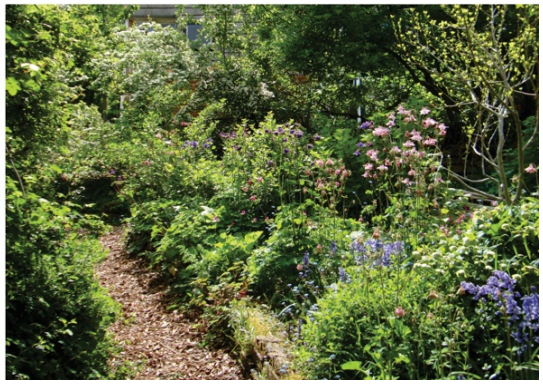


While not always the case, this is most commonly achieved by directing stormwater from the roof of a building and collecting it in a cistern below the structure. The runoff can then be filtered and treated before being reused on site or discharged into the city drainage system. Cisterns below buildings do not provide for infiltration.


## Remove pavement to plant green

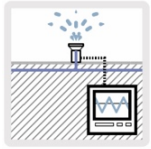
Pluvial flooding | Heatstress

Less paving in the garden and in urban areas has many advantages: the rainwater is absorbed into the ground, replenishing the groundwater. Paved surfaces get warmer in the summer than green space; removing paving creates more room for planting and the plants keep the area cooler on hot summer days. Removing paving offers animals, plants and soil life more space.



## Smart irrigation measures

Drought



If in times of prolonged drought there is a chance of damage to the vegetation, it must be irrigated. If this is done periodically (weekly), plants will become accustomed that this does not occur daily and will take root deeper in the soil. If irrigation is done late in the day there is also less loss through evaporation.

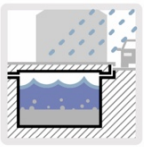
## Storage by creating extra freeboard

Pluvial flooding | Drought


Designing the surface area for storage to handle greater fluctuations in water levels is a way of realising storage capacity without requiring additional surface area. In many locations, however, the height required cannot simply be created by a high groundwater level. Greater fluctuations in water levels will place demands on how the banks are designed and planted, since those banks will be exposed to more extreme conditions.

## Storage tank or underground water storage

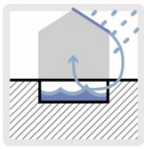
Pluvial flooding | Drought



Storage/settling tanks are designed to store excess runoff in urban drainage systems during wet periods. This is the case if runoff exceeds the discharge capacity of the urban drainage system.

## Systems for rainwater harvesting

Pluvial flooding | Drought



Rainwater harvesting is the collection and storage of stormwater for reuse on site. This is most commonly be achieved by capturing runoff from the roof of a building, however, it can also include the collection of runoff from throughout the site or byproducts from systems such as air conditioning condensate. The collection structures can take on multiple forms and be installed either above ground or subsurface. Depending on its source and treatment, the harvested water can be reused on site for irrigation.

## Urban Agriculture

Pluvial flooding | Heatstress | Drought

Urban agriculture is the practice of cultivating, processing, and distributing food in or around a community. Urban agriculture can also involve aquaculture, agroforestry, urban beekeeping, and horticulture. These activities can occur both in dense urban environments as well as within less dense, suburban areas.

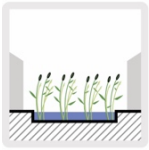
## Urban Forest

Heatstress | Pluvial flooding

Urban forests have many functions. Besides providing recreational space and contributing to a reduction in heat stress, they can create islands of relatively clean air in a city and improve the biodiversity. In addition, they contribute to limiting flooding, desiccation and salinization by infiltrating rainwater, and creating buffer and infiltration areas in the urban forests.

## Urban wetland

Pluvial flooding | Heatstress | Drought



Wetlands are water-rich natural areas that occur chiefly along rivers and in deltas. By their very nature, wetlands are overflow areas for rivers and as such are natural rainwater buffers. However, the urban expansions and the correspondingly lower groundwater levels put pressure on wetlands and wet nature around the world. In some cities, London for example, wetlands serve a function by developing greater biodiversity and natural and pleasant recreation areas for city dwellers.

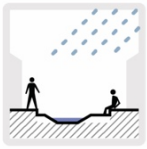
## Water roof

Pluvial flooding | Heatstress

Flat roofs can be designed to buffer a degree of precipitation by situating the overflow at a slightly higher level. This needs to be taken into account in the roof's construction (greater load). The rainwater is drained off at a delayed pace using narrower drainpipes and only remains for a short period on the roof to create sufficient storage capacity in time for the next rainfall.

## Water square

Pluvial flooding



Various towns and cities have designed systems to achieve rainwater retention in public spaces. These systems, known as water squares, are linked to other urban functions such as playing areas, green areas and residential functions. Water squares are generally used in inner-city areas with little room for water buffers and where high groundwater levels make infiltration impossible.

## Wetting Surfaces (of gardens, roofs, roads)

Heatstress

A sprinkler system can wet areas like roofs, roads or gardens so it can evaporate and cool down the air temperature. Other examples are fountains and waterfalls. This measure can be used in densely populated urban areas where the urban heat island effect is severe.

**References:**

Xiangtan Climate Resilient City Tool (https://xiangtan.crctool.org/en/)

Deltares (https://www.deltares.nl)