RAINSOLUTIONS

2020

# *Building on existing knowledge*

Project leader: Miklas Scholz
Lund University
5/31/2020

| | |
|---|---|
| **Contract Number** | |
| **Program name** | WJPI |
| **Project Title** | Research-based Assessment of Integrated approaches to Nature-based SOLUTIONS |
| **Project Acronym** | RainSolutions |
| **Version** | 1.0 |
| **Work package No.** | D.1. |
| **Deliverable Name** | Building on existing knowledge |
| **Short description** | Analysis of existing successful implementations of key nature-based technologies to build a common international knowledge base regarding best practice. |
| **Lead Beneficiary** | Lund University |
| **Type of document** | Report |
| **Dissemination Level** | |
| **Delivery date** | |
| **Contributor** | Kuno Kasak; Martin Maddison; Mikk Espenberg; Keit Kill; Ülo Mander; Török Liliana |

**Project Website**: https://www.rainsolutions.info
**Project code**: WaterWorks2017-RainSolutions

**Duration of project**: 3 years
**Start date**: 1 April 2019 **End date**: 30 March 2022

**Period covered by this report**: 1 September 2019 to 30 May 2020

**Please cite this article as:**

Kasak et al. 2020, Building on existing knowledge. Report D2., RainSolutions 43 pp., WaterWorks2017-RainSolutions

## Content

### Table of Contents





RAINSOLUTIONS

## List of figures, graphs, tables & annex

## Background information

The present report is produced in the frames the Water Joint Programming Initiative Water Challenges For A Changing World 2018 Joint Call Closing the Water Cycle Gap, according to the terms of the contract No. ………………….., between the Lead Partner (Lund University) and The WaterWorks2017 Follow-Up Secretariat

The report, entitled " Building on existing knowledge" was prepared by UT with the contribution of DDNI.

This report provide the results obtained during the first year of implementation of the project and is focused on the current state-of-the art of NBS in urban areas.
This WP explored existing successful implementations of the key nature-based technologies and challenges of their implementation.
Stakeholder and end user's attitude to adopt the NBS, as a way to identify catalysers, but also the main barriers such as costs, which were limiting the installation in urban areas have been also investigated.
The WP assessed previous projects concerning social inclusion through NBS, and assessed existing guidelines for planning and design of the different cost-effective solutions, as well as the potential for their transferability and training.

# 1. INTRODUCTION

Nature-based solutions (NBS) are actions, what are inspired by, supported by, or copied from nature. NBS are resource efficient and adapted in diverse spatial areas, facing social, environmental, and economic challenges (Somarakis, Stagakis, & Chrysoulakis, 2019). Nature based water management are considered sustainable solutions against shortage (droughts) and abundance (floods) of water in urban areas. Future climate models predict an increase of intensive rainfalls and also periods without precipitations all around the world. European Commission a has accepted along-term strategic vision to move to climate neutrality by 2050 (European Commission, 2019). NBS in urban areas are the enhancement of sustainable urbanization, helping the development of climate change adaptation and mitigation (Somarakis, Stagakis, & Chrysoulakis, 2019).

NBS including such as wetlands, ponds, green roofs, detention structures and permeable pavements, has reducing impact on urban heat flux (Augusto et al., 2020). However, they have not achieved wide-spread uptake, due to the gaps in knowledge regarding designing, implementing, and maintaining NBS or quantifying the benefits and co-benefits of their ecosystem services (Somarakis, Stagakis, & Chrysoulakis, 2019).

The benefits of NBS varies in space and time, due to various aspects (impact on individual, family, group, and a larger population) and scales (building and plot, district, regional). The assessment of their benefits is strongly related to complex thinking (Somarakis, Stagakis, & Chrysoulakis, 2019).

Most common barrier to implement NBS are the cost of system, availability of free space in urban area( depends on scale and capacity) and lack of confidence of decision makers and sucessful experience. Barriers are possible to cross by education (starting with kids in the scool, but also community and council level), increasing awarenes about climate change (discussion during project meeting in Oslo, 2019).

There are differents methods to assess the effectiveness and the quantification of NBS benefits using Life Cycle Assessment and Costing, evaluating comparable technical parameters(treatment efficiency, water retentions), public and private (incl. local business) feedback (discussion during project meeting in Oslo, 2019).

Our literature overview focus on finding succesful nature base water maangements solution by evaluating their technical parameters and through this evaluation shaping the attitude and motivation to adopt new solutions.

## 2. METHODOLOGICAL APPROACH

Analysis of references sources in order to summarise the state-of-the-art and gaps in knowledge regarding case studies, nations and international scene.

In this respect, a MetaData has been created with reference sources (Annex 1) and a Database (Annex 2) with information for data analysis of the successful implementations of the key nature-based technologies.

MetaData is link to the Goole Drive depository of NBS papers:
https://drive.google.com/drive/folders/1s4ZymCcOuil7xJMEd0So6YGOxLkgQErB

The overarching aim of the literature survey was to set focus for the most widely spread and implemented NBSs in the world. These measures include green roofs (GR), constructed wetlands (CW; also including detention and retention ponds), bioretention (BR), buffer strips (BS), rainwater harvesting (RWH), pearmable layer (PL) and swales (S). We reviewd 179 papers published in international peer-reviewd journals indexed by the Thomson Reuter Web of Science. The terms “green roof(s)”, “constructed wetland(s)”, “detention pond(s)”, “retention pond(s)”, “bioretention”, “buffer strip(s)”, “rainwater harvesting”, “pearmable layer” and “swale(s)” in combination with the terms “urban”, “cities”, “water retention”, “phosphorus (removal)”, “nitrogen (removal)”, “total suspended solids (removal)", "BOD7(5)", "storm" and "urban runoff" were searched. From the papers we collected the following data: annual temperature, annual precipitation, climate zone, climate (warm, wet; cold, wet; warm, dry; warm, wet), coordinates, depth of the NBS, area of the NBS, flow rate, removal efficiency of total phosphorus, total nitrogen and total suspended solids and water retention.

In total of 173 green roof, 17 permeable layer, 21 rainwater harvesting, 15 swales, 38 bioretention and 35 constructed wetland studies were analysed (Figure 1). The R program was used for the data analyses.

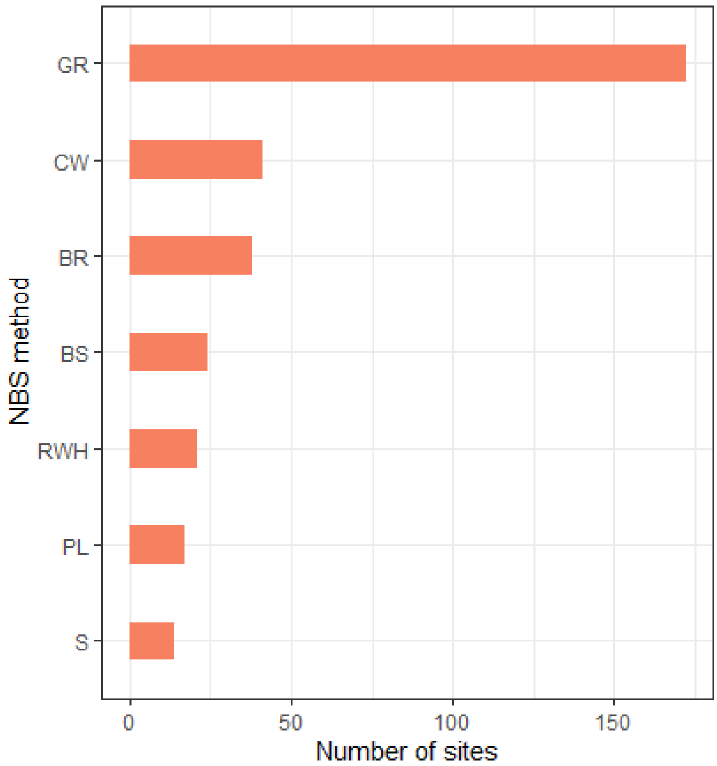



Figure 1. NBS methods for water retention in urban environment

## 3. RESULTS AND DISCUSSION

From the collected data, we first analysed to see what data is missing and how it affects further analyses. We saw that while the information about water retention is available in most of the studied green roofs and rainwater harvesting sites (Figure 3), it is almost completely absent in other solutions (Figure 2). Probabaly one of the reason is that while it is easy to analyse retention in green roofs and rainwater harvesting systems where there is controlled effluent. It is more challenging to analyse that in other solutions, therefore making it difficult to evaluate the overall potential of various NBSs in urban environment to retain water. In terms of pollutant data, we saw that BOD is absent in most of the solutions and therefore we excluded that in analyses, while TP, TN and TSS was available at least in half of the studied systems. The pollutant removal data in green roof and rainwater harvesting systems is difficult to evaluate, because they are usually designed to receive only precipitation that does not include excessive amount of pollutants, especially phosphorus compounds. Although, there have been some studies (e.g., Teemusk & Mander, 2007, 2011) where both nitrogen and phosphorus coumpounds are evaluated, their concentrations have been neglible.

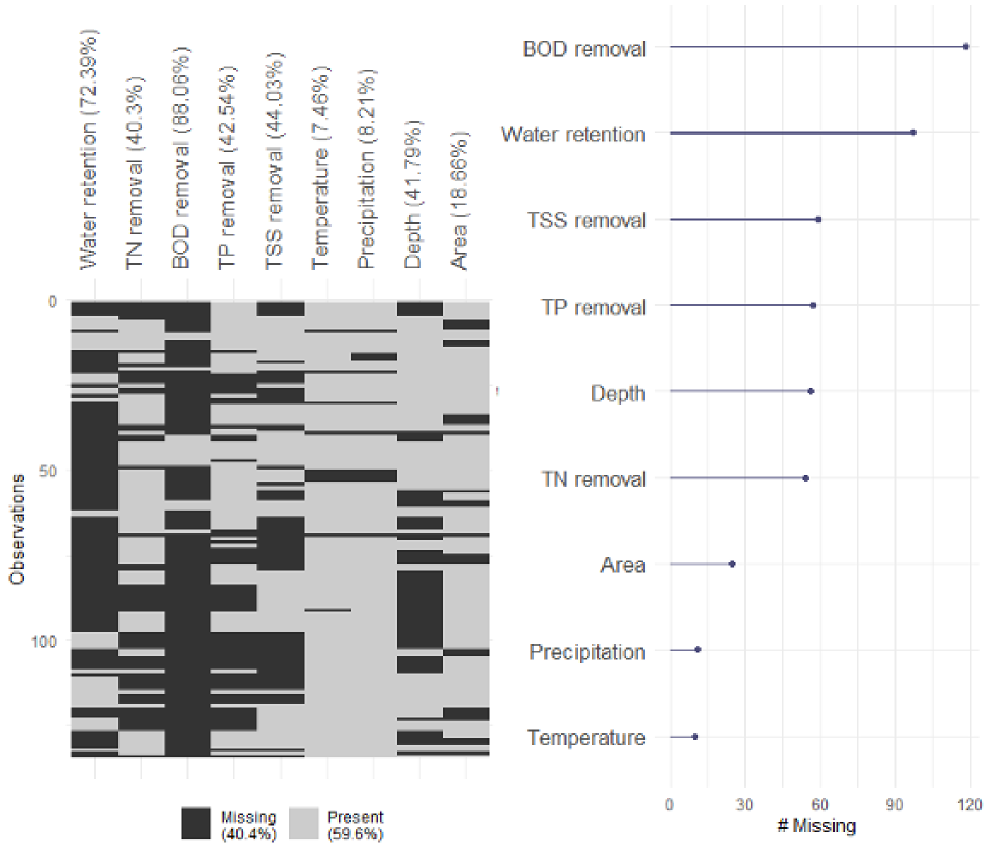



**Figure 2.** Missing data from PL, S, CW, BR and CW

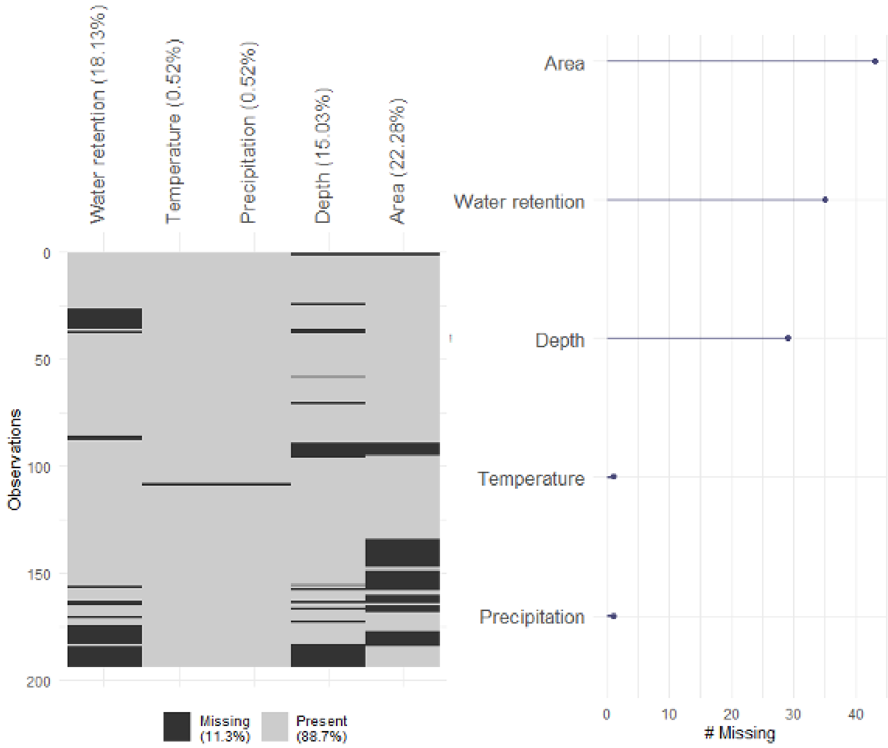



**Figure 3.** Missing data from green roofs and rainwater harvesting sites.

The water retention efficiency was highly variable in all solutions, however as seen in figure 4, the reliable data is only available for green roofs. For other solution the amount of data is scarce and therefore it is difficult to say what is the actual efficiency. For green roofs, the average water retention efficiency was 58% with maxium value of 99%. The average water rention for other measures was slightly higher or in a same range but due to the low amount of data there is still a lot of ambiguity. The total nitrogen removal was also higly variable in all solutions but the highest average efficiency was with permeable layer, which was 62%. The average removal efficiency of constructed wetlands was 42%. All other measures on the other hand showed very high variabilty and some of the systems even increased the total nitrogen concentration at the outflow. The highest increase of TN was observable with bioretention and buffer strips, where maximum effluent concentration increased 270% and 94%, respectively. This can be due to the sudden and rapid runoff that potentially have washed out the contaminants from the system. Total phosphorus removal was relatively good in bioretention, constructed wetlands and in permeable layer, where the average efficiency was 65.5%, 53.5% and 71.3%, respectively. However, some systems increased the concentration and for example, the average effluent concentration increased 66.7% and 51% in buffer strips and green roofs, respectively. The increase of pollutants in buffer strips, again probabaly is caused due to the sudden flood or changes in filter media. The increase in green roofs is probabaly related to fertilisers that are sometimes used to increase the plant growth rate in the roofs. And due to the rainfall, these phosphorus compounds are probably washed out from the system. TSS removal efficiency was also highly variable and based on the available data, the highest efficiency was with green roofs and with permeable layer, however this is based only on few data points (Figure 4).

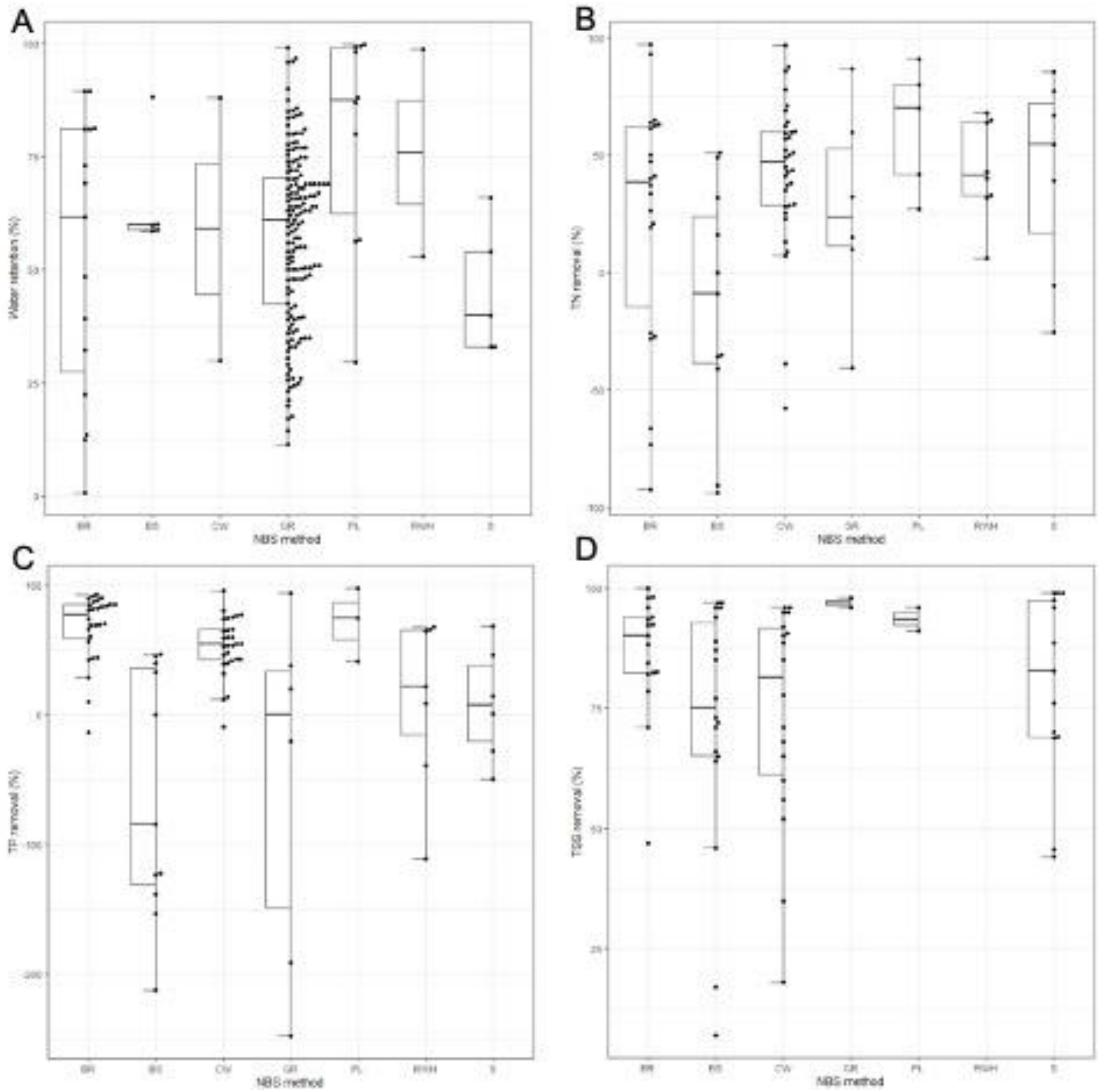


**Figure 4.** Water retention (A), TN removal (B), TP removal (C) and TSS removal (D) with different NBS. Box and whisker plot represent median values with 25th and 75th percentiles and with min-max values.

Since green roofs had the highest amount of available data about water retention, we used that information to analyse how different design parameters such as area and depth will affect water retention efficiency in different climate (Figures 5-6). As can be seen in figure 5, the highest water retention efficiency was in warm and dry climate, while in warm and wet climate it was lowest. This shows that the green roof efficiency to retain precipitation in rainy conditions is lower. Mostly due to the water saturation. In dry condition, green roofs are able to retain more water and in dry ccondition usually the rainfall is much more rapid and therefore its efficiency is higher. In wet climate, the precipitation is often continuous with few massive storm but overall the efficiency is lower. This on the other hand does not mean that green roofs are not efficient in wet climate. Figure 6. shows that the thickness of green roof is highly important for water retention. And thicker the greef roof material is, the higher amount of water it is able to retain.

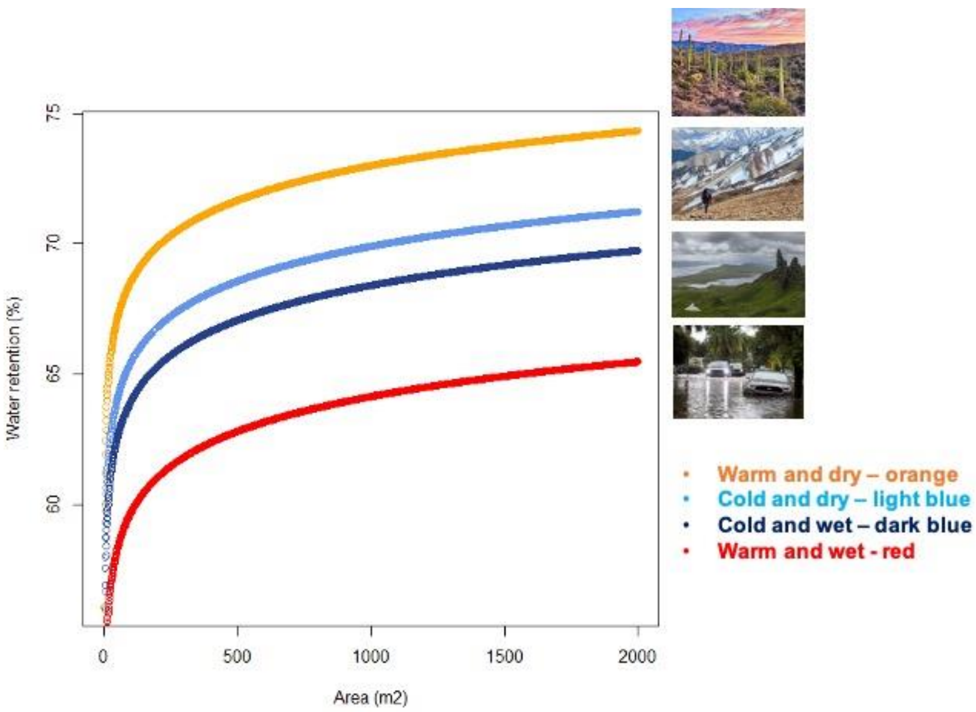



**Figure 5.** Modelled green roof water retention efficiency based on area and climate zone.

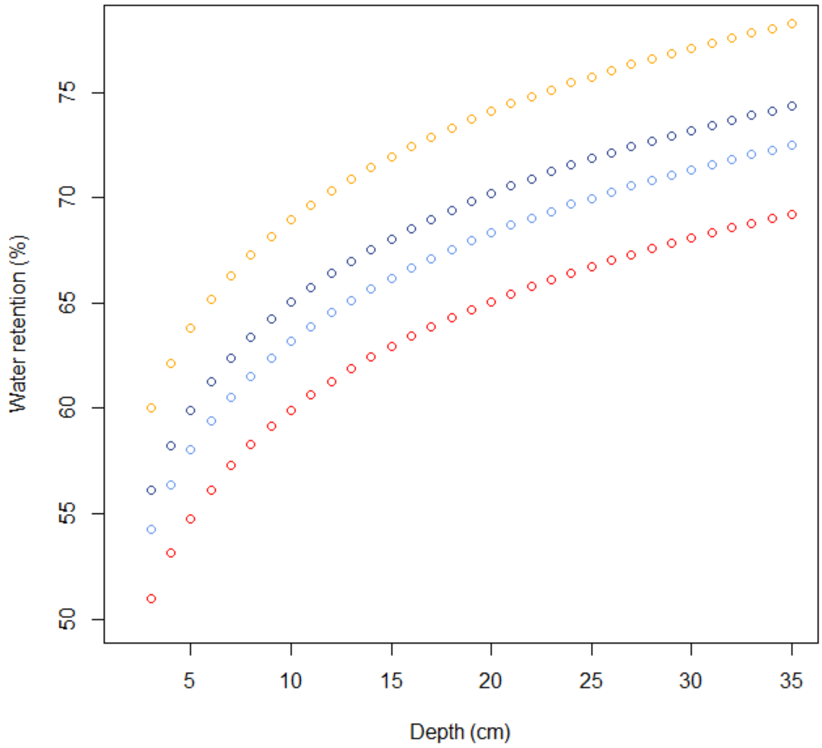



**Figure 6.** Modelled green roof water retention efficiency based on depth and climate zone.

A recent review by Sarabi et al., 2019 ("Key enablers of and barriers to the uptake and implementation of nature-based solutions in urban setting: a review") has brought out the main objectives for developing NBS:

- Climate change mitigation and adaption
- Water management
- Coastal resilience
- Green space management
- Air quality
- Urban regeneration
- Participatory planning and governance
- Social justice and social cohesion
- Public health and well-being
- Economic opportunities and green jobs.

The same paper also noted the main barriers to develop and implement NBS in urban environment that are as follows:

- Inadequate financial resources
- Path dependency
- Institutional fragmentation
- Inadequate regulations
- Uncertainty regarding implementation process and effectiveness of the solution
- Limited land and time availabilty.

Among these barries we found that another concern is the lack of available data to evaluate if some of the measures are efficient enough for water retention or for water treatment. For green roofs the amount of available data gives and great opportunity to evaluet the efficiency and therefore could serve as a good basis for future recommendation. From the barriers we can also see that one of the crucial issues is also the availabilty of land. For example, in dense urban environment it is difficult to built large systems and therefore these measures often end up in peri-urban areas where their efficiency is lower. The best methods in densely populated areas are solutions that can be built on top of roof or to the walls, e.g. green roofs, green walls and rainwater harvesting. These measures do not require any land from the streets and therefore are much easier to implement. In addition to potential water retention, they are also important to reduce the urban heat.

As we saw, there are a lot of barriers for the successful implementation but Sarabi et al.. (2019) also brought out key enablers that are:

- Partnership among stakeholders
- Knowledge sharing mechanisms and technologies
- Economic intruments
- Plans, acts and legislations
- Education and training
- Effective monitoring and valuation systems for implementation process and benefit
- Open innovation and experimentation
- Combining NBS with other urban elements and gray infrastructures

- Appropriate planning and design.

# 4. CONCLUSIONS AND RECOMMANDATIONS

We found that, although NBS has recently studied a lot in terms of potential barriers and enablers, there is still lack of information about the efficiency of various measures. Various guidelines (e.g. urban planning) are suggesting different NBS to reduce flooding and pollution, however we can see that there still a lot of missing information. For example, some of the measures are well studies not only in urban environment but also elsewhere (e.g. constructed wetlands, buffer strips) and therefore have a lot if information about potential treatment efficiency. But on the other hand, as we saw from previous figure, the data about water retention capacity is missing in most cases. And if urban planning is done that also include various measures to mitigate flooding, there is a missing information about the real efficiency. Therefore, more case stdues has to be done to investigate the efficiency of different measures. Hence, if more precise information about the effieicny is available it is more efficienct to recommend measure to stakeholdsers and descicion makers and this could reduce some of the barriers for implementation. For example, green roofs are well studies in terms of their water retention capacity and therefore easy to recommend. On the other hand, we donät know much about the actual water retention capacity of permeable layer, constructed wetlands, swales etc.

# 5. REFERENCES

Adyel T. M., 2017, Constructed wetlands for urban stormwater nutrient attenuation: Diurnal to decadal dynamics. Thesis for Doctor of Philosophy of The University of Western Australia. School of Civil, Environmental and Mining Engineering & UWA School of Agriculture and Environment, p. 174

Alam T., Mahmoud A., Jones K. D., Bezares-Cruz J. C., Guerrero J., 2019, A Comparison of Three Types of Permeable Pavements for Urban Runoff Mitigation in the Semi-Arid South Texas, U.S.A. Water 11, 1992; doi:10.3390/w11101992

Bangs C., 2007, Urban Stormwater Treatment by Experimental Constructed Wetlands. Engineering 90 Senior Design Project, p. 67, Swarthmore College Department of Engineering

Barrett M., Lantin A., Austrheim-Smith S., 2004, Storm water pollutant removal in roadside vegetated buffer strips. Transportation Research Record: Journal of the Transportation Research Board, 1890: 129–140.

Bäckström M., 2003, Grassed swales for stormwater pollution control during rain and snowmelt. Water Science and Technology 48 (9): 123-134

Bäckström M., 2002, Sediment transport in grassed swales during simulated runoff events. Water Science and Technology 45 (7): 41-49

Bean E. Z., Hunt W. F., Bidelspach D. A., 2007, Evaluation of Four Permeable Pavement Sites in Eastern North Carolina for Runoff Reduction and Water Quality Impacts. Journal of Irrigation and Drainage Engineering 133(6): 583-592

Beecham S., Razzaghmanesh M., 2015, Water quality and quantity investigation of green roofs in a dry climate. Water research 70: 370-384

Berndtssona J. Cz., Bengtssona L., Jinno K., 2009, Runoff water quality from intensive and extensive vegetated roofs. Ecological Engineering 35: 369-380. doi:10.1016/j.ecoleng.2008.09.020

Billore S.K., Singh N., Sharma J.K., Dass P., Nelson R.M., 1999, Horizontal subsurface flow gravel bed constructed wetland with Phragmites karaka in central India. Wat. Sci. Tech. 40 (3): 163-171

Birch G. F., Matthai C., Fazeli M. S., Suh J. Y., 2004, Efficiency of a constructed wetland in removing contaminants from stormwater. Wetlands, 24(2): 459-466

Blecken G.-T., 2010, Biofiltration Technologies for Stormwater Quality Treatment, Doctoral Thesis L., p. 222, Luleå University of Technology Sweden, ISSN: 1402-1544, ISBN 978-91-7439-132-9

Blecken G.-T., Zinger Y., Muthanna T.M., Deletic A., Fletcher T.D., Viklander M., 2007, The influence of temperature on nutrient treatment efficiency in stormwater biofilter systems. Water Science & Technology 56 (10): 83–91

Blecken G-T., Zinger Y., Deletic´ A., Fletcher T.D., Hedström A., Viklander M., 2010, Laboratory study on stormwater biofiltration: Nutrient and sediment removal in cold temperatures. Journal of Hydrology, 394 (3–4): 507-514

Braswell A. S., Anderson A. R., Hunt III W. F., 2018, Hydrologic and Water Quality Evaluation of a Permeable Pavement and Biofiltration Device in Series Water 10, 33; doi:10.3390/w10010033

Bratieres K., Fletcher T.D., Deletic A., Zinger Y., 2008, Nutrient and sediment removal by stormwater biofilters: A large-scale design optimisation study. WaterResearch 42: 3930–3940. doi:10.1016/j.watres.2008.06.009

Brattebo B. O., Booth D. B., 2003, Long-term stormwater quantity and quality performance of permeable pavement systems. Water Research 37: 4369–4376. doi:10.1016/S0043-1354(03)00410-X

Braswell A. S., Winston R. J., Hunt W. F., 2018, Hydrologic and water quality performance of permeable pavement with internal water storage over a clay soil in Durham, North Carolina. Journal of Environmental Management 224: 277-287

Brown R. A., Birgand F., Hunt W. F., 2013, Analysis of consecutive events for nutrient and sediment treatment in field-monitored bioretention cells. Water Air Soil Pollut 224:1581. DOI 10.1007/s11270-013-1581-6

Buccola N., Spolek G., 2011, A Pilot-Scale Evaluation of Greenroof Runoff Retention, Detention, and Quality. Water Air Soil Pollut 216:83–92. DOI 10.1007/s11270-010-0516-8

Carter T. L., Rasmussen T. C., 2006, Hydrologic behavior of vegetated roofs. Journal of the American Water Resources Association pp. 1261-1274

Cerezo G. R., Suárez M.L., Vidal-Abarca M.R., 2001, The performance of a multi-stage system of constructed wetlands for urban wastewater treatment in a semiarid region of SE Spain. Ecological Engineering 16: 501–517

Chang Ni-B., Wen D., Colona W., Wanielista M.P., 2019, Comparison of Biological Nutrient Removal via Two Biosorption-Activated Media Between Laboratory-Scale and Field-Scale Linear Ditch for Stormwater and Groundwater Co-treatment. Water Air Soil Pollut (2019) 230: 151 https://doi.org/10.1007/s11270-019-4193-y

Cho K. W., Song K. G., Cho J. W., Kim T. G., Ahn K. H., 2009, Removal of nitrogen by a layered soil infiltration system during intermittent storm events. Chemosphere 76: 690–696. doi:10.1016/j.chemosphere.2009.03.025

Choi J. Y., Maniquiz-Redillas M. C., Hong J. S., Lee S. Y., Kim L. H., 2015, Comparison of the treatment performance of hybrid constructed wetlands treating stormwater runoff. Water Science & Technology 72.12: 2243-2250. doi: 10.2166/wst.2015.443

Collins K. A., Hunt W. F., Hathaway J. M., 2007, Hydrologic and water quality comparison of four types of permeable pavement and standard asphalt in Eastern North Carolina. Report. 91 p., Biological and Agricultural Engineering Department, North Carolina State University

Collins K. A., Hunt W. F., Hathaway J.M., 2010, Side-by-Side Comparison of Nitrogen Species Removal for Four Types of Permeable Pavement and Standard Asphalt in Eastern North Carolina. Journal of Hydrologic Engineering 15 (6): 512-521, ISSN1084-0699/2010/6-512–521

Davis A. P., Traver R. G., Hunt W.F., Lee R., Brown R. A., Olszewski J.M., 2012, Hydrologic performance of bioretention storm-water control measures. Journal of Hydrologic Engineering 17(5): 604-614. DOI: 10.1061/(ASCE)HE.1943-5584.0000467

Deletic A., Fletcher T. D., 2006, Performance of grass filters used for stormwater treatment—a field and modelling study. Journal of Hydrology 317: 261–275

Dietz M. E., Clausen J. C., 2005, A field evaluation of rain garden flow and pollutant treatment. Water, Air, and Soil Pollution 167: 123–138

Dušek J., Picek T., Čížková H., 2008, Redox potential dynamics in a horizontal subsurface flow constructed wetland for wastewater treatment: Diel, seasonal and spatial fluctuations. Ecological Engineering 34: 223–232

Elliott S., Meyer M. H., Sands G. R., Horgan B., 2011, Water quality characteristics of three rain gardens located within the twin cities metropolitan area, Minnesota. Cities and the Environment (CATE) 4(1): 15p., http://digitalcommons.lmu.edu/cate/vol4/iss1/4

Erickson A.J., Gulliver J. S., Weiss P.T, 2007, Enhanced sand filtration for storm water phosphorus removal. Journal of Environmental Engineering 485 – 497. DOI: 10.1061/ASCE0733-93722007133:5485

Farrell A. C., Scheckenberger R. B., 2003, An Assessment of Long-Term Monitoring Data for Constructed Wetlands for Urban Highway Runoff Control. Water Qual. Res. J. Canada 38 (2): 283–315

Fassman-Beck E., Voyde E., Simcock R., Hong Y. S., 2013, 4 Living roofs in 3 locations: Does configuration affect runoff mitigation? Journal of Hydrology 490: 11-20

Fioretti R., Palla A., Lanza L.G., Principi P., 2010, Green roof energy and water related performance in the Mediterranean climate. Building and Environment 45: 1890-1904. doi:10.1016/j.buildenv.2010.03.001

Franzaringa J., Steffana L., Ansel W., Walker R., Fangmeier A., 2016, Water retention, wash-out, substrate and surface temperatures of extensive green roof mesocosms—Results from a two year study in SW-Germany. Ecological Engineering 94: 503-515. https://doi.org/10.1016/j.ecoleng.2016.06.021

García-Serrana M., Gulliver J. S., Nieber J. L., 2017, Infiltration capacity of roadside filter strips with non-uniform overland flow. Journal of Hydrology 545: 451-462

Getter K. L., Rowe B. D., Andresen J. A., 2007, Quantifying the effect of slope on extensive green roof stormwater retention. Ecological Engineering 31: 225-231. doi:10.1016/j.ecoleng.2007.06.004

Gikas G. D., Tsihrintzis V. A., 2012, Assessment of water quality of first-flush roof runoff and harvested rainwater. Journal of Hydrology 466–467: 115-126. https://doi.org/10.1016/j.jhydrol.2012.08.020

Goh H. W., Lai C. H., Zakaria N. A., 2017, Long-term performance of enhanced bioretention media under nutrient rich runoff in tropical climate. Proceedings of the 37th IAHR World Congress, pages 4258- 4263, ISSN 1562-6865, Malaysia

Goh H. W., Lau T. L., Foo K. Y., Zakaria N. A., 2014, Preliminary study on potential additives in filter media of bioretention for nutrient removal. 13th International Conference on Urban Drainage, Sarawak, Malaysia, 7□12 September 2014

Goh H.W., Zakaria N.A., Lau T.L., Foo K.Y., Chang C.K., Leow C.S., 2015, Mesocosm study of enhanced bioretention media in treating nutrient rich stormwater for mixed development area, Urban Water Journal, DOI: 10.1080/1573062X.2015.1076861

Graceson A., Hare M., Monaghan J., Hall N., 2013, The water retention capabilities of growing media for green roofs. Ecological Engineering 61: 328-334. https://doi.org/10.1016/j.ecoleng.2013.09.030

Gregoire B. G., Clausen J. C., 2011, Effect of a modular extensive green roof on stormwater runoff and water quality. Ecological Engineering 37: 963-969. doi:10.1016/j.ecoleng.2011.02.004

Harper G.E., Limmer M. A., Showalter W. E., Burken J. G., 2015, Nine-month evaluation of runoff quality and quantity from an experimental green roof in Missouri, USA. Ecological Engineering 78: 127-133

Headley T.R., Huett D.O., Davison L., 2001, The removal of nutrients from plant nursery irrigation runoff in subsurface horizontal-flow wetlands. Water Science and Technology 44 (11-12): 77-84

Hsieh C-H., Davis A.P., Needelman B.A., 2007, Bioretention column studies of phosphorus removal from urban stormwater runoff. Water Environment Research, 79 (2): 177-184. doi:10.2175/106143006X111745

Hunt W. F., Lord W.G., 2006 (?), Bioretention performance, design, construction, and maintenance. Urban Waterways 9p. North Carolina Cooperative Extension Service, 1/06—JL/DB AGW-588-05. E06-44609

Hurley S. E., Forman R.T.T., 2011, Stormwater ponds and biofilters for large urban sites: Modeled arrangements that achieve the phosphorus reduction target for Boston's Charles River, USA. Ecological Engineering 37: 850-863, doi:10.1016/j.ecoleng.2011.01.008

Hutchinson D., Abrams P., Retzlaff R., Liptan T., 2003, Stormwater monitoring two ecoroofs in Portland, Oregon, USA. Greening Rooftops for Sustainable Communities: Chicago 18pp., www.greenroofs.ca

Ivanovsky A., Belles A., Criquet J., Dumoulin D., Noble P., Alary C., Billon G., 2018, Assessment of the treatment efficiency of an urban stormwater pond and its impact on the natural downstream watercourse. Journal of Environmental Management 226: 120-130. https://doi.org/10.1016/j.jenvman.2018.08.015

Jianga C., Lia J., Lia H., Lib Y., 2019, Nitrogen retention and purification efficiency from rainfall runoff via retrofitted bioretention cells. Separation and Purification Technology 220: 25-32

Kim H.J., Choi J-W., Kim T-H., Park J-S., An B., 2018, Effect of TSS removal from stormwater by mixed media column on T-N, T-P, and organic material removal. Water, 10, 1069; doi:10.3390/w10081069 www.mdpi.com/journal/water

Kohler E.A., Poole V.L., Reicher Z.J. , Turco R.F., 2004, Nutrient, metal, and pesticide removal during storm and nonstorm events by a constructed wetland on an urban golf course. Ecological Engineering 23: 285–298

Kuoppamäki K., Hagner M., Lehvävirta S., Setälä H., 2016, Biochar amendment in the green roof substrate affects runoff quality and quantity. Ecological Engineering 88: 1-9, https://doi.org/10.1016/j.ecoleng.2015.12.010

Lee B-H., Scholz M., 2007, What is the role of Phragmites australis in experimental constructed wetland filters treating urban runoff? Ecological Engineering 29: 87–95, doi:10.1016/j.ecoleng.2006.08.001

Li H., Sharkey L. J., Hunt W.F., Davis A. P., 2009, Mitigation of impervious surface hydrology using bioretention in North Carolina and Maryland. Journal of Hydrologic Engineering, 14 (4): 407-415, ISSN 1084-0699/2009/4-407–415. DOI: 10.1061/ASCE1084-0699200914:4407

Li M-H., Barrett M. E., Rammohan P., Olivera F., Landphair H. C., 2008, Documenting stormwater quality on Texas highways and adjacent vegetated roadsides. Journal of Environmental Engineering page 48-59. DOI: 10.1061/ASCE0733-93722008134:148

Li XX., Cao J J., Xu P X., Fei L., Dong Q., Wang Z L., 2018, Green roofs: Effects of plant species used on runoff. Land Degrad Dev., 29: 3628–3638

Liu W., Feng Q., Chen W., Wei W., Deo R. C., 2019, The influence of structural factors on stormwater runoff retention of extensive green roofs: new evidence from scale-based models and real experiments. Journal of Hydrology 569: 230-238

Liu W., Wei W., Chen W., Deo R. C., Si J., Xi H., Li B., Feng Q, 2019, The impacts of substrate and vegetation on stormwater runoff quality from extensive green roofs Journal of Hydrology 576: 575-582

Lucke T., Nichols P. W.B., 2015, The pollution removal and stormwater reduction performance of street-side bioretention basins after ten years in operation. Science of The Total Environment 536: 784-792

Malcolm E. G., Reese M. L., Schaus M. H., Ozmon I.M., Tran L. M., 2014, Measurements of nutrients and mercury in green roof and gravel roof runoff. Ecological Engineering 73: 705-712. https://doi.org/10.1016/j.ecoleng.2014.09.030

Mendez C. B., Klenzendorf J. B., Afshar B. R., Simmons M. T., Barrett M. E., Kinney K. A., Kirisits M. J., 2011, The effect of roofing material on the quality of harvested rainwater. Water Research 45 (5): 2049-2059

Muha N.E., Sidek L.M., Jajarmizadeh M., 2016, Water quality improvement through reductions of pollutant loads on small scale of bioretention system. International Conference on Advances in Renewable Energy and Technologies (ICARET 2016) Earth and Environmental Science 32 (2016) 012010. doi:10.1088/1755-1315/32/1/012010

Nawaz R., McDonald A., Postoyko S., 2015, Hydrological performance of a full-scale extensive green roof located in a temperate climate. Ecological Engineering 82: 66-80. https://doi.org/10.1016/j.ecoleng.2014.11.061

Palla A., Sansalone J. J., Gnecco I., Lanza L. G., 2001, Storm water infiltration in a monitored green roof for hydrologic restoration. Water Science & Technology 64.3: 766-773

Sailor D., Bass B., 2014, Development and features of the Green Roof Energy Calculator. Journal of Living Architecture. 1(3): 36-58.

Scholes L.N.L., Shutes R. B. E., Revitt D.M., Purchase D., Forshaw M., 1999, The removal of urban pollutants by constructed wetlands during wet weather. Wat. Sci. Tech. 40 (3): 333-340

Schroll E., Lambrinos J., Righetti T., Sandrock D., 2011, The role of vegetation in regulating stormwater runoff from green roofs in a winter rainfall climate. Ecological Engineering 37: 595-600. https://doi.org/10.1016/j.ecoleng.2010.12.020

Seidl M., Gromaire M-C., Saad M., De Gouvello B., 2013, Effect of substrate depth and rain-event history on the pollutant abatement of green roofs. Environmental Pollution 183: 195-203. https://doi.org/10.1016/j.envpol.2013.05.026

Seters T. V., Rocha L., Smith D., MacMillan G., 2009, Evaluation of Green Roofs for Runoff Retention, Runoff Quality,and Leachability. Water Qual. Res. J. Can. 44 (1): 33-47

Soulis K. X., Ntoulas N., Nektarios P. A., Kargas G., 2017, Runoff reduction from extensive green roofs having different substrate depth and plant cover. Ecological Engineering 102: 80-89 https://doi.org/10.1016/j.ecoleng.2017.01.031

Speak A.F., Rothwell J.J., Lindley S.J., Smith C.L., 2013, Rainwater runoff retention on an aged intensive green roof. Science of The Total Environment 461-462: 28-38, https://doi.org/10.1016/j.scitotenv.2013.04.085

Speak A.F., Rothwell J.J., Lindley S.J., Smith C.L., 2014, Metal and nutrient dynamics on an aged intensive green roof, Environmental Pollution 184: 33-43. https://doi.org/10.1016/j.envpol.2013.08.017

Stagge J. H., Davis A. P., Jamil E., Kim H., 2012, Performance of grass swales for improving water quality from highway runoff. Water Research 46 (20): 6731-6742. https://doi.org/10.1016/j.watres.2012.02.037

Stovin V., Vesuviano G., Kasmin H., 2012, The hydrological performance of a green roof test bed under UK climatic conditions. Journal of Hydrology 414-415: 148-161

Takaijudin H. B., 2016, Hydraulic conductivity study in engineered soil media for stormwater runoff treatment in bioretention facility.Thesis for the Degree of Doctor of Philosophy (PhD), p.286, Universiti Sains Malaysia

Teemusk A., Mander Ü, 2007, Rainwater runoff quantity and quality performance from a greenroof: The effects of short-term events. Ecological Engineering 30: 271-277. doi:10.1016/j.ecoleng.2007.01.009

Teemusk A., Mander Ü., 2011, The Influence of Green Roofs on Runoff Water Quality: A Case Study from Estonia. Water Resour Manage 25:3699–3713. DOI 10.1007/s11269-011-9877-z

Terzakis S., Fountoulakis M.S., Georgaki I., Albantakis D., Sabathianakis I., Karathanasis A.D., Kalogerakis N., Manios T., 2008, Constructed wetlands treating highway runoff in the central Mediterranean region. Chemosphere 72: 141–149

Thomas A., Morrison R. J., Gangaiya P., Miskiewicz A. G., Chambers R. L., Powell M., 2016, Constructed wetlands as urban water constructed wetlands as urban water quality control ponds - studies on reliability and effectiveness. Wetlands Australia Journal, 28 (1), 2-14.

Uhl M., Schiedt L., 2008, Green Roof Storm Water Retention –Monitoring Results. 11th International Conference on Urban Drainage, Edinburgh, Scotland, UK, 11 pp.

VanWoert N. D., Rowe D. B., Andresen J. A., Rugh C. L., Fernandez R. T., Xiao L., 2005, Green Roof Stormwater Retention: Effects of Roof Surface, Slope, and Media Depth. Journal of Environmental Quality 34: 1036-1044

Ventura D., Barbagallo S., Consoli S., Ferrante M., Milani M., Licciardello F., Cirelli G. L., 2019, On the performance of a pilot hybrid constructed wetland for stormwater recovery in Mediterranean climate. Water Science & Technology 79.6: 1051-1059, doi: 10.2166/wst.2019.103

Vijayaraghavan K., Raja F. D., 2015, Pilot-scale evaluation of green roofs with Sargassum biomass as an additive to improve runoff quality. Ecological Engineering 75: 70-78. https://doi.org/10.1016/j.ecoleng.2014.11.029

Volder A., Dvorak B., 2014, Event size, substrate water content and vegetation affect storm water retention efficiency of an un-irrigated extensive green roof system in Central Texas. Sustainable Cities and Society 10: 59-64, https://doi.org/10.1016/j.scs.2013.05.005

Voyde E., Fassman E., Simcock R., 2010, Hydrology of an extensive living roof under sub-tropical climate conditions in Auckland, New Zealand. Journal of Hydrology 394: 384-395. https://doi.org/10.1016/j.jhydrol.2010.09.013

Weng G.H., Liang, L.T., Yuen F. K., Kiat C. C., Zakaria N.A., 2015, Influence of Hydraulic Conductivity and Organic Matter Content in Different Bioretention Media on Nutrient Removal. Applied Mechanics and Materials 802: 448-453 doi:10.4028/www.scientific.net/AMM.802.448

Winston R. J., Hunt W. F., Osmond D. L., Lord W. G., Woodward M. D., 2011, Field evaluation of four level spreader–vegetative filter strips to improve urban storm-water quality. Journal of Irrigation and Drainage Engineering 137(3): 170-182. DOI: 10.1061/(ASCE)IR.1943-4774.0000173.

Wong G. K.L., Jim C.Y., 2014, Quantitative hydrologic performance of extensive green roof under humid-tropical rainfall regime. Ecological Engineering 70: 366-378. https://doi.org/10.1016/j.ecoleng.2014.06.025

Wu J., Cao X., Zhao J., Dai Y., Cui N., Li Z., Cheng S., 2017, Performance of biofilter with a saturated zone for urban stormwater runoff pollution control: Influence of vegetation type and saturation time. Ecological Engineering 105 (355-361)

Zhang Z., Rengel Z., Liaghati T., Antoniette T., Meney K., 2011, Influence of plant species and submerged zone with carbon addition on nutrient removal in stormwater biofilter. Ecological Engineering 37 (11): 1833-1841, https://doi.org/10.1016/j.ecoleng.2011.06.016

Zhanga Q., Miao L., Wang X., Liu D., Zhua L., Zhou B., Sun J., Liua J., 2015, The capacity of greening roof to reduce stormwater runoff and pollution. Landscape and Urban Planning 144: 142-150. https://doi.org/10.1016/j.landurbplan.2015.08.017

Augusto, B., Roebeling, P., Rafael, S., Ferreira, J., Ascenso, A., Bodilis, C. (2020). Short and medium- to long-term impacts of nature-based solutions on urban heat. Sustainable Cities and Society, 57. doi: 10.1016/j.scs.2020.102122

Vidya Venkataramanan, Denise Lopez, David J. McCuskey, Daniel Kiefus, Robert I. McDonald, William M. Miller, Aaron I. Packman, Sera L. Young. (2020). Knowledge, attitudes, intentions, and behavior related to green infrastructure for flood management: A systematic literature review,

Science of The Total Environment, 720. doi.: 10.1016/j.scitotenv.2020.137606

Somarakis, G., Stagakis, S., & Chrysoulakis, N. (Eds.). (2019). ThinkNature Nature-Based Solutions Handbook. ThinkNature project funded by the EU Horizon 2020 research and innovation programme under grant agreement No. 730338. doi:10.26225/ jerv-w202

European Commission. (2018). Going climate-neutral by 2050-A strategic long-term vision for a prosperous, modern, competitive and climate-neutral EU economy. EU publications.

***Disclaimer:*** *The oppinions in this material is not necessarely reprezenting the oppinion of the financial body.*

## ANNEX 1

| NBS | Annual temperature | Annual Precipitation (mm) | Climate | depth (cm) | Area (m2) | TN removal % | TP removal% | BOD removal (%) | TSS removal % | water retention % | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BF | 9.8 | 1120 | cold, wet | | 74000 | | 90.5 | | | | Hurley and Forman 2011 |
| BF | 9.7 | 1127 | cold, wet | | 74000 | | 88.5 | | | | Hurley and Forman 2011 |
| BF | 9.8 | 1120 | cold, wet | | 81000 | | 87 | | | | Hurley and Forman 2011 |
| BF | 9.7 | 1127 | cold, wet | | 81000 | | 85.25 | | | | Hurley and Forman 2011 |
| BF | 16.1 | 1049 | warm, wet | 0.27 | 1.4 | | 29 | | 47 | 0.7 | Brasswell et al 2018 |
| BR | 20.3 | 1578 | warm, wet | 200 | | -92.7 | 85.3 | | -30.4 | 39.15 | Lucke & Nichols 2015 |
| BR | 20.3 | 1578 | warm, wet | 200 | | -25.78 | 73.92 | | -42.85 | 61.6 | Lucke & Nichols 2015 |
| BR | 20.3 | 1578 | warm, wet | 200 | | 26.2 | 60.23 | | -52.3 | 81.2 | Lucke & Nichols 2015 |
| BR | | | warm, wet | 55 | 0.025 | 63.3 | 81.9 | | 90.1 | | Weng et al 2015 |
| BR | 27.4 | 2336 | warm, wet | 80 | 16 | -27.2 | 42.5 | 71.8 | 88.3 | 81.1 | TAKAIJUDIN thesis 2016 |
| BR | 27.4 | 2336 | warm, wet | 80 | 16 | -270.5 | -13.6 | 73.3 | 82.4 | 69.2 | TAKAIJUDIN thesis 2016 |
| BR | 15.1 | 1091 | warm, wet | 60 | | 21 | 10 | | 71 | 89.54 | Brown et al 2013; brown and hunt 2011 |
| BR | 15.1 | 1091 | warm, wet | 90 | | 19 | 44 | | 82 | 89.54 | Brown et al 2013; brown and hunt 2011 |
| BR | 27.4 | 1329 | warm, wet | 65 | 0.15 | 63.96 | 89.7 | | 9318 | 12.49 | Goh et al 2015 |
| BR | 5.2 | 884 | cold, wet | 70 | 959 | | | | 100 | | Blecken 2010 thesis |
| BR | 10 | | | 90 | 0.11 | -73.3 | 80.73 | | 969 | | Blecken et al 2007 |
| BR | 10 | | | 90 | 0.11 | -66.6 | 91.3 | | 98 | | Blecken et al 2010 |
| BR | 20 | 681 | warm, dry | 80 | 0.0707 | 93 | 93 | | | | Zhang et al 2011 |
| BR | 12.7 | 1034 | warm, wet | 40 | 0.032 | | 70.5 | | 94 | | Hsieh et al 2007 |
| BR | 12 | 1350 | warm, wet | 65 | 0.36 | 47.5 | 56.5 | 56.95 | 82.5 | | Kim et al 2018 |
| BR | | | | 56 | 0.0254 | | 44.5 | | | | Erickson et al 2007 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BR | 12.6 | 1125 | warm, wet | 90 | 102 | | | | | 22.5 | Davis et al 2012 |
| BR | 9.3 | 1045 | cold, wet | 120 | 149 | | | | | 48.4 | Davis et al 2012 |
| BR | 15.3 | 1146 | warm, wet | 110 | 146 | | | | | 13.6 | Davis et al 2012 |
| BR | 13 | 1124 | warm, wet | 65 | 181 | 41 | | | 96 | | Li et al 2009; Li and Davis 2014 |
| BR | 14.8 | 1163 | warm, wet | 55 | 162 | | | | | 73 | Li et al 2009 |
| BR | 14.8 | 1163 | warm, wet | 55 | 99 | | | | | 81 | Li et al 2009 |
| BR | 16.1 | 1150 | warm, wet | 105 | 0.125 | 50.1 | 69.7 | | | | Wu et al 2017 |
| BR | 14.8 | 560 | warm, dry | 105 | 0.2 | 62.39 | | | | 32.23 | Jiang, et al. 2019 |
| BR | | | | 130 | 0.075 | 97.3 | | | | | Cho et al 2009 |
| BR | 14.8 | 653 | warm, wet | 81 | 0.1875 | -28.4 | 84.4 | | 98.1 | | Bratieres et al 2008 |
| BR | 27.1 | 999.9 | warm, wet | 100 | 48 | 61.4 | 82.1 | | 92.2 | | Muha et al 2016 |
| BR | 27.1 | 999.9 | warm, wet | 100 | 48 | 64.7 | 83.3 | | 92.4 | | Muha et al 2016 |
| BR | 27.5 | 1329 | warm, wet | 60 | | 33.5 | 66 | | 78.5 | | TAKAIJUDIN et al 2017? |
| BR | 27.5 | 1329 | warm, wet | 70 | | 36.9 | 69.4 | | 84.4 | | TAKAIJUDIN et al 2017? |
| BR | 27.5 | 1329 | warm, wet | 80 | | 40 | 69.5 | | 93.4 | | TAKAIJUDIN et al 2017? |
| BR | 27 | 2000 | warm, wet | 80 | 0.15 | | | | | | Goh et al 2017 |
| BR | 27.4 | 2304 | warm, wet | 50 | 0.025 | | 84.7 | | | | Goh et al 2014 |
| BS | | | warm, dry | | | 0 | 0 | | 87 | | Jiang et al. 2015, Barrett et al. 1995 |
| CW | 9.8 | 650 | cold, wet | | 360 | | | 29 | 18 | | #VALUE! |
| CW | 11.1 | 822 | cold, wet | | 1750 | | | 24 | 35 | | #VALUE! |
| CW | 27.1 | 2307 | warm, wet | 8.5 | 4000000 | 60 | 53 | 44 | 56 | | Nur Asmaliza Mohd Noor et al. 2017 |
| CW | 21 | 237 | warm, dry | 80 | 3 | 38 | 66 | 90 | 90 | | Cerezo et al 2001 |
| CW | 21 | 237 | warm, dry | 80 | 3 | 41 | 55 | 90 | 96 | | Cerezo et al 2001 |
| CW | 21 | 237 | warm, dry | 80 | 3 | 23 | 48 | 88 | 96 | | Cerezo et al 2001 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CW | 21 | 237 | warm, dry | 80 | 3 | 78 | 60 | 90 | 95 | | Cerezo et al 2001 |
| CW | 25.2 | 1032 | warm, wet | 85 | 41.8 | 59.4 | | 65.1 | 77.75 | | #VALUE! |
| CW | 7.9 | 634 | cold, dry | 90 | 748 | 62.6 | 75.4 | 82 | 52 | | Dušek et al 2008 |
| CW | 10.3 | 970 | warm, wet | 120 | 19500 | | 74 | | | | Kohler et al 2004 |
| CW | | | | 27.5 | 66 | 43.5 | 53.5 | | 85 | | Terzakis et al 2008 |
| CW | | | | 27.5 | 66 | 28.5 | 59.5 | | 88.5 | | Terzakis et al 2008 |
| CW | | | | 47.5 | 64 | 50 | 60 | | 90.5 | | Terzakis et al 2008 |
| CW | | | | 47.5 | 64 | 57.5 | 65.5 | | 92 | | Terzakis et al 2008 |
| CW | 18.9 | 1717 | warm, wet | 50 | 4 | 87.4 | 80.15 | | | | Headley et al 2001 |
| CW | 17.6 | 1074.7 | warm, wet | 2 | 800 | 9 | 12 | | -4 | | Birch et al 2004 |
| CW | 12.2 | 1113 | warm, wet | | | 7 | 14 | | | | Bangs 2007 |
| CW | 18.7 | 910 | warm, wet | | 9000 | 57 | 53.7 | | | | Adyel 2017 thesis |
| CW | 18.7 | 770 | warm, wet | | 10000 | 45 | 65 | | | | Adyel 2017 thesis |
| CW | 7 | 700 | cold, wet | | | 35 | 43 | 40 | 68 | | Farrel & schenken 2003 |
| CW | 7 | 700 | cold, wet | | | 13 | 46 | 15 | 60 | | Farrel & schenken 2003 |
| CW | 17.8 | 567 | warm, dry | 85 | 27.25 | 37 | 40 | 50 | 65 | | Ventura et al 2019 |
| CW | 11.8 | 1279 | warm, wet | 100 | 23 | 97 | 96 | | 95 | 88 | Choi et al 2015 |
| CW | 11.8 | 1431 | warm, wet | 70 | 6.5 | 49 | 42 | | 71 | 30 | Choi et al 2015 |
| CW | 22.9 | 1100 | warm, wet | | 11400 | 69 | 43 | | | | Thomas et al 2016 |
| CW | 22.9 | 1100 | warm, wet | | 11400 | -39 | -9 | | | | Thomas et al 2016 |
| CW | 22.9 | 1100 | warm, wet | | 11400 | 71 | 75 | | | | Thomas et al 2016 |
| CW | 22.9 | 1100 | warm, wet | | 11400 | -58 | 32 | | | | Thomas et al 2016 |
| CW | 8.5 | 706 | cold, wet | 83 | 0.008 | 59.65 | | 87.3 | | | Lee and Schols 2007 |
| CW | | | | | | | | | | | Vymazal, 2007 |
| CW | 24 | 1440 | warm, wet | | 27000 | 42,7 | 55 | | | | Nesbit and Mitsch 2018 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CW | 23.9 | 200 | warm, dry | 87.5 | 420000 | 28 | | | | | Sanchez et al. 2016 |
| CW | 17.6 | 340 | warm, dry | 50 | 1860000 | 64.3 | 39.3 | | | | Ibekwe et al. 2007 |
| CW | 18.2 | 300 | warm, dry | 77 | 99000 | 52 | | | | | Smith et al. 2000 |
| CW | 21.6 | 300 | warm, dry | | 124600 | 29 | | | | | Kmiec & Thomure 2015 |
| CW | 23.9 | 200 | warm, dry | | | 86 | | | | | Palta et al. 2017 |
| CW | 23.9 | 200 | warm, dry | | | 51 | | | | | Palta et al. 2017 |
| CW | 14.7 | 1010 | warm, wet | | | 25.5 | | | | | Harrison et al. 2011 |
| DP | 9.8 | 1120 | cold, wet | 106.5 | 112300 | | 76.8 | | | | Hurley and Forman 2011 |
| DP | 9.7 | 1127 | cold, wet | 106.5 | 121500 | | 77.2 | | | | Hurley and Forman 2011 |
| FS | 15 | 1089 | warm, wet | | 80.1 | 32 | 40 | | 72 | | Winston et al 2011 |
| FS | 15 | 1089 | warm, wet | | 42.6 | 16 | 33 | | 65 | | Winston et al 2011 |
| FS | 14.8 | 1163 | warm, wet | | 86.5 | 51.1 | 46.7 | | 88.9 | | Winston et al 2011 |
| FS | 14.8 | 1163 | warm, wet | | 38.9 | 49.2 | 45.6 | | 73.1 | | Winston et al 2011 |
| FS | 15.9 | 470 | warm, dry | | 4.75 | | | | 85 | | Barret 2004 |
| FS | 16.9 | 355 | warm, dry | | 9.2 | | | | 96 | | Barret 2004 |
| FS | 16.8 | 879 | warm, wet | | 4.2 | | | | 97 | | Barret 2004 |
| FS | 14.4 | 899 | warm, wet | | 8.3 | | | | 96 | | Barret 2004 |
| FS | 17.8 | 393 | warm, dry | | 7.4 | | | | 94 | | Barret 2004 |
| FS | 17.2 | 366 | warm, dry | | 8 | | | | 97 | | Barret 2004 |
| FS | 17.2 | 379 | warm, dry | | 6.25 | | | | -450 | | Barret 2004 |
| FS | | 338 | warm, dry | | 5.6 | | | | 77 | | Barret 2004 |
| FS | 19.9 | 1018 | warm, wet | | 185 | -35 | -84 | | 17 | | Li et al 2008 |
| FS | 19.9 | 1018 | warm, wet | | 218 | -94 | -153 | | 46 | | Li et al 2008 |
| FS | 19.9 | 1018 | warm, wet | | 185 | -41 | -138 | | 7 | | Li et al 2008 |
| FS | 20.1 | 870 | warm, wet | | 185 | -91 | -123 | | 64 | | Li et al 2008 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| FS | 20.1 | 870 | warm, wet | | 185 | -9 | -122 | | 66 | | Li et al 2008 |
| FS | 20.1 | 870 | warm, wet | | 185 | -36 | -212 | | 71 | | Li et al 2008 |
| FS | 8.3 | 762 | cold, wet | | 1.68 | | | | | 59.8 | Deletic and Fletcher 2006 |
| FS | 7.1 | 814 | cold, wet | | 4 | | | | | 58.9 | García-Serrana et al 2017 |
| FS | 7.1 | 814 | cold, wet | | 4 | | | | | 60.1 | García-Serrana et al 2017 |
| FS | 7.1 | 814 | cold, wet | | 7 | | | | | 58.6 | García-Serrana et al 2017 |
| FS | 7.1 | 814 | cold, wet | | 4 | | | | | 88.2 | García-Serrana et al 2017 |
| GR | 16.1 | 1150 | warm, wet | | | | | | | 24.5 | Li et al 2018 |
| GR | 12.5 | 830 | cold, wet | 5 | 2000 | | | | | 26 | Sailor ja Bass 2014 |
| GR | 12.5 | 830 | cold, wet | 15 | 2000 | | | | | 39.5 | Sailor ja Bass 2014 |
| GR | 10.7 | 810 | warm, wet | 10 | 2000 | | | | | 59 | Sailor ja Bass 2014 |
| GR | 10.7 | 810 | warm, wet | 10 | 2000 | | | | | 90 | Sailor ja Bass 2014 |
| GR | 10.4 | 360 | warm, dry | 10 | 2000 | | | | | 99 | vanWoert et al 2005 |
| GR | 10.4 | 360 | warm, dry | 10 | 1000 | | | | | 50 | Sailor ja Bass 2014 |
| GR | 7 | 421 | warm, dry | 5 | 1 | | | | | 25.7 | Liu et al 2019 (two articles) |
| GR | 7 | 421 | warm, dry | 10 | 1 | | | | | 42.1 | Liu et al 2019 (two articles) |
| GR | 7 | 421 | warm, dry | 15 | 1 | | | | | 36.2 | Liu et al 2019 (two articles) |
| GR | 7 | 421 | warm, dry | 5 | 1 | | | | | 41.5 | Liu et al 2019 (two articles) |
| GR | 7 | 421 | warm, dry | 10 | 1 | | | | | 36.7 | Liu et al 2019 (two articles) |
| GR | 7 | 421 | warm, dry | 15 | 1 | | | | | 33.8 | Liu et al 2019 (two articles) |
| GR | 7 | 421 | warm, dry | 5 | 1 | | | | | 34.8 | Liu et al 2019 (two articles) |
| GR | 7 | 421 | warm, dry | 10 | 1 | | | | | 17.6 | Liu et al 2019 (two articles) |
| GR | 7 | 421 | warm, dry | 15 | 1 | | | | | 23.1 | Liu et al 2019 (two articles) |
| GR | 7 | 421 | warm, dry | 5 | 1 | | | | | 40.6 | Liu et al 2019 (two articles) |
| GR | 9 | 785 | cold, wet | 5.5 | 1.63 | | | | | 50.4 | VanWoert et al 2005 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GR | 9 | 785 | cold, wet | 5.5 | 1.63 | | | | | 60.6 | VanWoert et al 2005 |
| GR | 9 | 785 | cold, wet | 5.5 | 5.95 | | | | | 70.25 | VanWoert et al 2005 |
| GR | 9 | 785 | cold, wet | 5.5 | 5.95 | | | | | 67 | VanWoert et al 2005 |
| GR | 22.6 | 2400 | warm, wet | 4 | 1.1 | | | | | 39.45 | Wong&Jim 2014 |
| GR | 22.6 | 2400 | warm, wet | 8 | 1.1 | | | | | 44.8 | Wong&Jim 2014 |
| GR | 25.6 | 1400 | warm, dry | | 0.25 | | | | | 65.7 | Vijayaraghavan, Raja 2015 |
| GR | 15.1 | 1093 | warm, wet | 5 | 235 | | | | | 87.5 | Voyde et al 2010 |
| GR | 5 | 732 | cold, wet | 18 | 120 | | | | | 85.7 | Teemusk, Mander 2011; Teemusk, Mander 2007 |
| GR | 5.3 | 732 | cold, wet | 14 | 100 | | | | | | Teemusk, Mander 2011 |
| GR | 5.3 | 732 | cold, wet | 14 | 100 | | | | | | Teemusk, Mander 2011 |
| GR | 5 | 732 | cold, wet | 11 | 1.5 | | | | | | Teemusk, Mander 2011 |
| GR | 5 | 732 | cold, wet | 9 | 1.5 | | | | | | Teemusk, Mander 2011 |
| GR | 5.2 | 732 | cold, wet | 18 | 35 | | | | | | Teemusk, Mander 2011 |
| GR | 5.1 | 732 | cold, wet | 18 | 50 | | | | | | Teemusk, Mander 2011 |
| GR | 5.1 | 732 | cold, wet | 20 | 50 | | | | | | Teemusk, Mander 2011 |
| GR | 4.6 | 732 | cold, wet | 20 | 70 | | | | | | Teemusk, Mander 2011 |
| GR | 5 | 732 | cold, wet | 20 | 30 | | | | | | Teemusk, Mander 2011 |
| GR | 15.6 | 1182 | warm, wet | | 1 | | | | | 72 | Malcolm et al 2014 |
| GR | 15.6 | 1182 | warm, wet | | 415 | | | | | | Malcolm et al 2014 |
| GR | 11.9 | 96 | cold, wet | 7.6 | 235 | | | | | 39 | Hutchinson et al 2003 |
| GR | 11.9 | 96 | cold, wet | 12 | 243 | | | | | 69 | Hutchinson et al 2003 |
| GR | 9 | 690 | cold, wet | 8 | 24.3 | | | | | 61 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 25 | 12 | | | | | 80 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 25 | 12 | | | | | 81 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 15 | 12 | | | | | 74 | Uhl and Schiedt 2008 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GR | 9 | 690 | cold, wet | 5 | 12 | | | | | 67 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 5 | 12 | | | | | 73 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 10 | 12 | | | | | 69 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 10 | 24.1 | | | | | 62 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 10 | 25 | | | | | 69 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 15 | 25.1 | | | | | 69 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 10 | 12 | | | | | 71 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 15 | 12 | | | | | 77 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 15 | 12 | | | | | 77 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 10 | 12 | | | | | 69 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 4 | 12 | | | | | 64 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 8 | 17.6 | | | | | 69 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 8 | 24.2 | | | | | 64 | Uhl and Schiedt 2008 |
| GR | 9 | 690 | cold, wet | 8 | 12 | | | | | 67 | Uhl and Schiedt 2008 |
| GR | 8.1 | 785 | cold, wet | | 5.95 | | | | | 80.2 | Getter et al 2007 |
| GR | 15.2 | 1200 | warm, wet | 6 | 217 | | | | | 66 | Fassman-Beck et al 2013 |
| GR | 15.2 | 1200 | warm, wet | 10 | 4 | | | | | 48 | Fassman-Beck et al 2013 |
| GR | 15.2 | 1200 | warm, wet | 15 | 4 | | | | | 57 | Fassman-Beck et al 2013 |
| GR | 15.2 | 1200 | warm, wet | 10 | 171 | | | | | 66 | Fassman-Beck et al 2013 |
| GR | 13 | 1059 | warm, wet | 10.2 | 3.696 | | | | | 54.2 | Harper et al 2015 |
| GR | 13 | 1059 | warm, wet | 10.2 | 3.696 | | | | | 45.3 | Harper et al 2015 |
| GR | 16.4 | 546 | warm, dry | 30 | 0.15 | | | | | 76.96 | Beecham and Razzaghmanesh 2015 |
| GR | 16.4 | 546 | warm, dry | 10 | 0.15 | | | | | 71.65 | Beecham and Razzaghmanesh 2015 |
| GR | 11 | 700 | cold, wet | 6 | 4 | | | | 96 | 84.1 | Seidl et al 2013 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GR | 11 | 700 | cold, wet | 16 | 4 | | | | 98 | 83.7 | Seidl et al 2013 |
| GR | 10.5 | 828,8 | cold, wet | 17 | 408 | -40.6 | -20 | | | 65.7 | Speak et al 2013, 2014 |
| GR | 3.9 | 647 | cold, wet | | 0.2 | | 20 | | | 70 | Kuoppamäki et al 2016 |
| GR | 9.6 | 824 | cold, wet | 8 | 3 | | | | | 50.2 | Stovin et al 2012 |
| GR | 11.2 | 1107 | cold, wet | 13 | 3.6 | | | | | 42.55 | Schroll et al 2011 |
| GR | 19.9 | 1017,5 | warm, wet | 11 | 0.36 | | | | | 77.7 | Volde and Dvorak 2014 |
| GR | 18.1 | 465,6 | warm, dry | 8 | 2 | | | | | 54.98 | Soulis et al 2017 |
| GR | 18.1 | 465,6 | warm, dry | 16 | 2 | | | | | 66.25 | Soulis et al 2017 |
| GR | 9.3 | 968 | cold, wet | 13 | 0.26 | | | | | 34.6 | Franzaring et al 2016 |
| GR | 9.5 | 1154 | cold, wet | 13 | 830 | | | | | 66.21 | Nawaz et al 2015 |
| GR | 11.9 | 914 | cold, wet | 5 | 0.36 | | | | | 28 | Buccola and Spolek (2011) |
| GR | 11.9 | 914 | cold, wet | 14 | 0.36 | | | | | 60 | Buccola and Spolek (2011) |
| GR | 9.3 | 1307 | warm, wet | 10.2 | 248 | 32.1 | -191 | | | 51.4 | Gregoire and Clausen (2011) |
| GR | 16.2 | 1232 | warm, wet | 8 | 42.64 | | | | | 78 | Carter and Rasmussen (2006) |
| GR | 8.3 | 785 | cold, wet | 14 | 241 | 15.1 | -247.6 | | | 63 | Seters et al. (2009) |
| GR | 10.1 | 925 | cold, wet | 7,5 | 1 | | | | | 39,8 | Graceson et al 2013 |
| GR | 10.1 | 925 | cold, wet | 15 | 1 | | | | | 47.7 | Graceson et al 2013 |
| GR | 14.7 | 1086 | warm, wet | 35 | 350 | | | | | 68 | Fioretti et al. (2010), Palla et al. (2011) |
| GR | 16.4 | 1600 | warm, wet | 40 | 2.16 | | | | | | Berndtsson et al 2009 |
| GR | 8.1 | 600 | cold, dry | 3 | 5 | | | | | | Berndtsson et al 2009 |
| GR | 19 | 1200 | warm, wet | 17 | 1 | | | | | 68 | Zhang et al 2015 |
| GR | 9.9 | 1283 | warm, wet | | | | | | | 35 | Talebi et al 2019 |
| GR | 3.4 | 428 | cold, dry | | | | | | | 53 | Talebi et al 2019 |
| GR | 2.4 | 384 | cold, dry | | | | | | | 61 | Talebi et al 2019 |
| GR | 7.4 | 946 | cold, wet | | | | | | | 38 | Talebi et al 2019 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GR | 8.3 | 785 | cold, wet | | | | | | | 48 | Talebi et al 2019 |
| GR | 6.5 | 1410 | cold, wet | | | | | | | 27 | Talebi et al 2019 |
| GR | 9.4 | 1055 | cold, wet | | 1190 | | | | | 95.9 | Todorov et al 2018 |
| GR | 13.5 | 900 | warm, wet | 6 | 4.9 | | | | | 85 | Ferrans et al 2018 |
| GR | 11.2 | 633 | cold, wet | 10 | 0.012 | | | | | 20 | Dusza et al 2017 |
| GR | 11.2 | 633 | cold, wet | 30 | 0.012 | | | | | 33 | Dusza et al 2017 |
| GR | 11 | 820 | cold, wet | 8 | 2.25 | | | | | 67.9 | Yilmaz et al 2016 |
| GR | 11 | 820 | cold, wet | 12 | 2.25 | | | | | 74.9 | Yilmaz et al 2016 |
| GR | 11 | 820 | cold, wet | 8 | 2.25 | | | | | 72.8 | Yilmaz et al 2016 |
| GR | 11 | 820 | cold, wet | 12 | 2.25 | | | | | 80.2 | Yilmaz et al 2016 |
| GR | 11 | 820 | cold, wet | 12 | 2.25 | | | | | 75.3 | Yilmaz et al 2016 |
| GR | 11 | 820 | cold, wet | 12 | 2.25 | | | | | 74.9 | Yilmaz et al 2016 |
| GR | 11.9 | 1373 | warm, wet | 15 | 1 | | | | | 24.1 | Young Lee et al 2015 |
| GR | 11.9 | 1373 | warm, wet | 20 | 1 | | | | | 51.8 | Young Lee et al 2015 |
| GR | 8.1 | 785 | cold, wet | 10.5 | 1.92 | | | | | 85.2 | Whittinghill et al 2015 |
| GR | | | | 15 | 0.37 | 87 | 38 | | | 21.13 | Beck et al 2011 |
| GR | 8.4 | 551 | cold, wet | 35 | 2.88 | | | | | 64.75 | Burszta-Adamiak 2012 |
| GR | 22 | 2500 | warm, wet | 15 | 0.288 | | | | | 74.33 | Fang 2010 |
| GR | 12.4 | 541 | warm, dry | 10 | 0.35 | | | | | 48.8 | Wang et al 2017 |
| GR | 26.8 | 2378 | warm, wet | 25 | 4 | | | | | 11.4 | Qin et al. 2012 |
| GR | 26.6 | 2325 | warm, wet | 20 | 0.75 | | | | | 32 | Musa et al 2008 |
| GR | 3.4 | 428 | cold, dry | 15 | 52 | | | | | 83.6 | Sims et al. 2016 |
| GR | 7.4 | 846 | cold, wet | 15 | 65 | | | | | 76.5 | Sims et al. 2016 |
| GR | 6.5 | 1196 | cold, wet | 15 | 55 | | | | | 59.6 | Sims et al. 2016 |
| GR | 16 | 1287 | warm, wet | 10.2 | 27 | | | | | 63 | Moran et al. 2003 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GR | 16 | 1233 | warm, wet | 7.5 | 70 | | | | | 62 | Moran et al. 2003 |
| GR | 12.1 | 1144 | warm, wet | 3 | 0,5 | | | | | 36 | Carson et al. 2013 |
| GR | 12.1 | 1144 | warm, wet | 10 | 12 | | | | | 54 | Carson et al. 2013 |
| GR | 9.4 | 1055 | cold, wet | 10 | 1190 | 59.55 | 93.75 | | | 96.8 | Carpenter et al. 2016 |
| GR | 12.1 | 1144 | warm, wet | 3 | 310 | | | | | 60 | Hakimdavar et al. 2014 |
| GR | 12.1 | 1144 | warm, wet | 3 | 99 | | | | | 64 | Hakimdavar et al. 2014 |
| GR | 12.1 | 1144 | warm, wet | 3 | 0.09 | | | | | 56 | Hakimdavar et al. 2014 |
| GR | 20.1 | 811 | warm, wet | 10 | 3.4 | | | | | 37.1 | Simmons et al. 2008 |
| GR | 16.2 | 1232 | warm, wet | 7.6 | 42.64 | | | | | 78 | Carter and Rasmussen 2006 |
| GR | 12 | 1219 | warm, wet | 16 | 12 | | | | | 81.9 | Nardini et al. 2012 |
| GR | 7.8 | 653 | cold, dry | 4 | 1.54 | | | | | 35 | Villarreal and Bengtsson 2005 |
| GR | 9.9 | 1117 | warm, wet | 35 | 1500 | | | | | 48 | Johnston et al. 2004 |
| GR | 9.9 | 1155 | warm, wet | 15 | 33 | | | | | 29 | Connelly et al. 2006 |
| GR | 9.9 | 1155 | warm, wet | 7.5 | 33 | | | | | 26 | Connelly et al. 2006 |
| GR | 11.9 | 940 | cold, wet | 12.5 | 290 | | | | | 14.5 | Spolek 2008 |
| GR | 11.9 | 940 | cold, wet | 15 | 500 | | | | | 25 | Spolek 2008 |
| GR | 8.3 | 785 | cold, wet | 14 | 241 | | | | | 63 | Van Seters et al. 2009 |
| GR | 9.3 | 995 | cold, wet | 9.5 | | | | | | 52.6 | Berghage et al. 2009, Akther et al 2018 |
| GR | 8.1 | 784 | cold, wet | 4 | | | | | | 69 | Rowe et al. 2003, Akther et al 2018 |
| GR | 8.1 | 784 | cold, wet | 6 | | | | | | 72 | Rowe et al. 2003, Akther et al 2018 |
| GR | 9.5 | 816 | cold, wet | 2 | | | | | | 39 | Russell and Schickedantz, 2003, Akther et al 2018 |
| GR | 9.5 | 816 | cold, wet | 10 | | | | | | 58 | Russell and Schickedantz, 2003, Akther et al 2018 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GR | 8.2 | 870 | cold, wet | 4 | | | | | | 48.35 | Monterusso et al. 2004, Akther et al 2018 |
| GR | 8.2 | 870 | cold, wet | 10 | | | | | | 84.46 | Carpenter and Kaluvakolanu 2011, Akther et al 2018 |
| GR | 12.5 | 1113 | warm, wet | 9 | | | | | | 58.5 | DeNardo et al. 2005, Akther et al 2018 |
| GR | 8.3 | 785 | cold, wet | 8.5 | | | | | | 57 | Liu and Minor 2005, Akther et al 2018 |
| GR | 8.3 | 785 | cold, wet | 14 | | | | | | 65.3 | TRCA (2006), Akther et al 2018 |
| GR | 10.9 | 969 | cold, wet | 15 | | | | | | 30.5 | Berkompas et al. 2008, Akther et al 2018 |
| GR | 10.9 | 969 | cold, wet | 11.25 | | | | | | 33 | Berkompas et al. 2008, Akther et al 2018 |
| GR | 10.9 | 969 | cold, wet | 15 | | | | | | 17.1 | Berkompas et al. 2008, Akther et al 2018 |
| GR | 16.4 | 536 | warm, dry | 10 | 0.15 | | | | | 51 | Beecham and Razzaghmanesh 2015, Akther et al 2018 |
| GR | 16.4 | 536 | warm, dry | 30 | 0.15 | | | | | 96 | Beecham and Razzaghmanesh 2015, Akther et al 2018 |
| GR | 10.6 | 943 | warm, wet | 14 | | | | | | 70 | Bliss et al 2009, Akther et al 2018 |
| GR | 10 | 918 | warm, wet | 12.5 | | | | | | 50 | Morgan et al. 2012, Akther et al 2018 |
| GR | 10 | 918 | warm, wet | 7.6 | | | | | | 74 | Berghage et al. 2010, Akther et al 2018 |
| GR | 11.9 | 1001 | cold, wet | 12.5 | | | | | | 56 | Kurtz 2008, Akther et al 2018 |
| GR | 11.9 | 1001 | cold, wet | 7.5 | | | | | | 64 | Kurtz 2008, Akther et al 2018 |
| GR | 11.5 | 799 | cold, wet | 6 | | | | | | 55 | Arias et al. 2016,Akther et al 2018 |
| GR | 13.5 | 866 | warm, wet | | | | | | | 76.7 | Perez et al 2016, Akther et al 2018 |

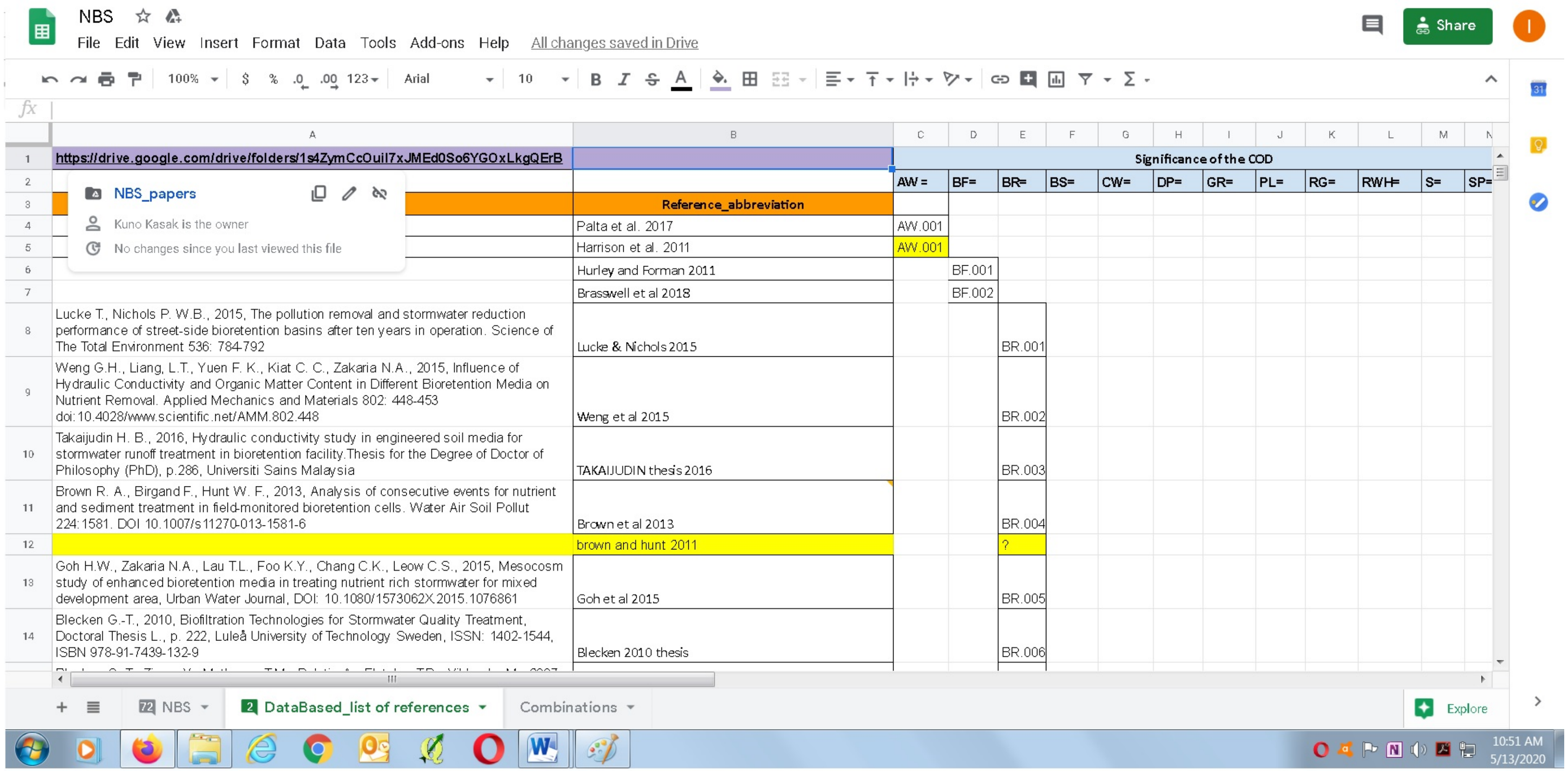
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GR | 10.2 | 653 | cold, wet | 9 | | | | | | | Gromaire et al. 2013, Akther et al 2018 |
| GR | 9.6 | 747 | cold, wet | | | | | | | 34 | Stovin 2010 , Akther et al 2018 |
| GR | 8.1 | 612 | cold, dry | 3 | 5 | | | | | 46 | Bengtsson et al. 2005, Akther et al 2018 |
| GR | 12.9 | 1045 | warm, wet | 10 | 0.4 | | | | | 50 | Harper et al. 2015, Akther et al 2018 |
| GR | 16 | 1233 | warm, wet | 7.5 | | | | | | 63 | Moran et al. 2005, Akther et al 2018 |
| GR | 15.3 | 1147 | warm, wet | 10 | | | | | | 55 | Moran et al. 2005, Akther et al 2018 |
| GR | 16 | 1233 | warm, wet | 10 | | | | | | 64 | Hathaway et al 2008, Akther et al 2018 |
| GR | 13.9 | 1151 | warm, wet | | | | | | | | Toladn et al 2012, Akther et al 2018 |
| GR | 22 | 2574 | warm, wet | 10 | 0.1 | | | | | | Chen and Kang 2016, Akther et al 2018 |
| GR | 26.6 | 2325 | warm, wet | 15 | | | | | | 66.5 | Kasmin and Musa ,2012, Akther et al 2018 |
| GR | 27.1 | 2486 | warm, wet | | | | | | | 51 | Kasmin et al. 2014, Akther et al 2018 |
| GR | 3.4 | 428 | cold, dry | 15 | | | | | | 62.5 | Alberta Ingenuity 2008, Akther et al 2018 |
| GR | 3.9 | 650 | cold, wet | 7 | 2 | | | | | 50.52 | Krebs et al 2016, Akther et al 2018 |
| GR | 12.1 | 610 | warm, dry | 15 | 120 | | | | | 78.27 | Yang et al 2015, Akther et al 2018 |
| GR | 12.4 | 541 | warm, dry | 22.5 | 0.5 | 9.9 | | | | | Wang et al 2013, Akther et al 2018 |
| GR | 10.3 | 360 | warm, dry | 10 | 1858 | | | | | 80 | Jiang et al. 2015, Tolderlund 2010 |
| GR | 10.3 | 360 | warm, dry | | 2000 | | | | | 68.7 | Jiang et al. 2015, Tolderlund 2010 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PL | 22 | 1500 | warm, wet | 90 | | 80 | | | | | Chang2019 |
| PL | 22 | 1500 | warm, wet | 45 | | 70 | | | | | Chang2019 |
| PL | 11.7 | 1016 | warm, dry | | 18 | | | | | | Brattebo, Booth 2003 |
| PL | 11.7 | 1016 | warm, dry | | 18 | | | | | | Brattebo, Booth 2003 |
| PL | 11.7 | 1016 | warm, dry | | 18 | | | | | | Brattebo, Booth 2003 |
| PL | 11.7 | 1016 | warm, dry | | 18 | | | | | | Brattebo, Booth 2003 |
| PL | 14.8 | 1259 | warm, wet | | 50 | 91 | 98 | | | 29.65 | Brasswell et al 2018 |
| PL | 17.1 | 1417 | warm, wet | 8 | 740 | | | | | | Bean et al 2007 |
| PL | 16 | 925 | warm, wet | 15 | 108 | | | | | 99.86 | collins et al 2007, 2010 |
| PL | 16 | 925 | warm, wet | 8 | 108 | | | | | 99.33 | collins et al 2007, 2010 |
| PL | 16 | 925 | warm, wet | 8 | 108 | | | | | 98.17 | collins et al 2007, 2010 |
| PL | 16 | 925 | warm, wet | 8 | 108 | | | | | 99.51 | collins et al 2007, 2010 |
| PL | 16.1 | 1049 | warm, wet | 40 | 215 | 27 | 41 | | 91 | 56.3 | Brasswell et al 2018 |
| PL | 23.2 | 695 | warm, wet | 46 | 37 | | | | | 87 | Alam et al 2019 |
| PL | 23 | 630 | warm, wet | 57 | 209 | | | | | 88 | Alam et al 2019 |
| PL | 23.2 | 695 | warm, wet | 38 | 372 | | | | | 80 | Alam et al 2019 |
| PL + BF | 16.1 | 1049 | warm, wet | 40 | 216 | 42 | 75 | | 96 | 56.6 | Brasswell et al 2018 |
| RG | 10.1 | 1204 | warm, wet | 60 | 9.2 | 32 | -110.6 | | | 98.8 | Dietz ja Clausen 2005 |
| RG | 8 | 774 | cold, wet | 0.7 | 405 | | | | | | Elliott et al 2011 |
| RG | 6.9 | 838 | cold, wet | 0.6 | 405 | | | | | | Elliott et al 2011 |
| RG | 7 | 985 | cold, wet | 2 | 4047 | | | | | | Elliott et al 2011 |
| RG | 14.6 | 1076 | warm, wet | 122 | | 33 | -39 | | | | Hunt&Lord2006 |
| RG | 14.6 | 1076 | warm, wet | 122 | | 43 | 9 | | | | Hunt&Lord2006 |
| RG | 14.7 | 1203 | warm, wet | 122 | | 40 | 65 | | | | Hunt&Lord2006 |
| RG | 14.8 | 1071 | warm, wet | 75 | | 64 | 66 | | | | Hunt&Lord2006 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RG | 14.8 | 1071 | warm, wet | 75 | | 68 | 22 | | | | Hunt&Lord2006 |
| RG | 15.4 | 1057 | warm, wet | 122 | | 65 | 68 | | | | Hunt&Lord2006 |
| RG | 10 | 417 | warm, dry | | | 6 | −473 | | −21 | 53 | Jiang et al. 2015 |
| RWH | 20.8 | 856 | warm, wet | | 2.8 | | | | | | Mendez et al 2011 |
| RWH | 20.8 | 856 | warm, wet | | 2.8 | | | | | | Mendez et al 2011 |
| RWH | 20.8 | 856 | warm, wet | | 2.8 | | | | | | Mendez et al 2011 |
| RWH | 20.8 | 856 | warm, wet | | 3.4 | | | | | | Mendez et al 2011 |
| RWH | 20.8 | 856 | warm, wet | | 3.4 | | | | | | Mendez et al 2011 |
| RWH | 14.2 | 551 | warm, dry | | 180 | | | | | | Gikas & Tsihrintzis 2012 |
| RWH | 14.1 | 541 | warm, dry | | 100 | | | | | | Gikas & Tsihrintzis 2012 |
| RWH | 14.1 | 541 | warm, dry | | 180 | | | | | | Gikas & Tsihrintzis 2012 |
| RWH | 15.3 | 541 | warm, dry | | 75 | | | | | | Gikas & Tsihrintzis 2012 |
| RWH | 14 | 542 | warm, dry | | 130 | | | | | | Gikas & Tsihrintzis 2012 |
| S | 1.4 | 494 | cold, dry | 0.456 | | | | | 99 | | Bäckström 2003 |
| S | 1.4 | 494 | cold, dry | 0.456 | | | | | 99 | | Bäckström 2003 |
| S | 1.4 | 494 | cold, dry | 0.456 | | | | | 96 | | Bäckström 2003 |
| S | 1.4 | 494 | cold, dry | | | | | | 70 | 54 | Bäckström 2003 |
| S | 1.4 | 494 | cold, dry | 5.8 | 7.5 | | | | 97.5 | 33 | Bäckström 2002 |
| S | 1.4 | 494 | cold, dry | 3.7 | 7.5 | | | | 99 | 66 | Bäckström 2002 |
| S | 1.4 | 494 | cold, dry | 4.8 | 7.5 | | | | 88.5 | 33 | Bäckström 2002 |
| S | 12.8 | 1105 | warm, wet | | 121 | -5.7 | -27.5 | | 44.1 | | Stagge et al 2012 |
| S | 12.8 | 1105 | warm, wet | | 84.2 | -25.6 | -49.2 | | 45.6 | | Stagge et al 2012 |
| S | 12.8 | 1105 | warm, wet | | | 77.2 | 14.7 | | 82.7 | | Stagge et al 2012 |
| S | 12.8 | 1105 | warm, wet | | | 85.6 | 68.7 | | 68.8 | | Stagge et al 2012 |
| S | 20.3 | 1168 | warm, wet | 7.44 | 130 | 54.4 | 46 | | 69 | | Deletic and Fletcher 2006 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 11.4 | 1219 | warm, wet | 130 | 9.3 | 39 | | | | 40 | Shetty et al 2019 |
| S | 17.6 | 322 | warm, dry | | | 67 | 1 | | 76 | | Jiang et al. 2015, Caltrans 2004 |
| SP | 10.1 | 699 | cold, dry | 150 | 330000 | | | | | | Ivanovski et al 2018 |

# ANNEX 2



| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | https://drive.google.com/drive/folders/1s4ZymCcOuil7xJMEd0So6YGOxLkgQErB | | Significance of the COD | | | | | | | | | | | |
| 2 | | | AW = | BF= | BR= | BS= | CW= | DP= | GR= | PL= | RG= | RWH= | S= | SP= |
| 3 | | Reference_abbreviation | | | | | | | | | | | | |
| 4 | | Palta et al. 2017 | AW.001 | | | | | | | | | | | |
| 5 | | Harrison et al. 2011 | AW.001 | | | | | | | | | | | |
| 6 | | Hurley and Forman 2011 | | BF.001 | | | | | | | | | | |
| 7 | | Braswell et al 2018 | | BF.002 | | | | | | | | | | |
| 8 | Lucke T., Nichols P. W.B., 2015, The pollution removal and stormwater reduction performance of street-side bioretention basins after ten years in operation. Science of The Total Environment 536: 784-792 | Lucke & Nichols 2015 | | | BR.001 | | | | | | | | | |
| 9 | Weng G.H., Liang, L.T., Yuen F. K., Kiat C. C., Zakaria N.A., 2015, Influence of Hydraulic Conductivity and Organic Matter Content in Different Bioretention Media on Nutrient Removal. Applied Mechanics and Materials 802: 448-453 doi:10.4028/www.scientific.net/AMM.802.448 | Weng et al 2015 | | | BR.002 | | | | | | | | | |
| 10 | Takaijudin H. B., 2016, Hydraulic conductivity study in engineered soil media for stormwater runoff treatment in bioretention facility.Thesis for the Degree of Doctor of Philosophy (PhD), p.286, Universiti Sains Malaysia | TAKAIJUDIN thesis 2016 | | | BR.003 | | | | | | | | | |
| 11 | Brown R. A., Birgand F., Hunt W. F., 2013, Analysis of consecutive events for nutrient and sediment treatment in field-monitored bioretention cells. Water Air Soil Pollut 224:1581. DOI 10.1007/s11270-013-1581-6 | Brown et al 2013 | | | BR.004 | | | | | | | | | |
| 12 | | brown and hunt 2011 | | | ? | | | | | | | | | |
| 13 | Goh H.W., Zakaria N.A., Lau T.L., Foo K.Y., Chang C.K., Leow C.S., 2015, Mesocosm study of enhanced bioretention media in treating nutrient rich stormwater for mixed development area, Urban Water Journal, DOI: 10.1080/1573062X.2015.1076861 | Goh et al 2015 | | | BR.005 | | | | | | | | | |
| 14 | Blecken G.-T., 2010, Biofiltration Technologies for Stormwater Quality Treatment, Doctoral Thesis L., p. 222, Luleå University of Technology Sweden, ISSN: 1402-1544, ISBN 978-91-7439-132-9 | Blecken 2010 thesis | | | BR.006 | | | | | | | | | |

**Table 1.** Min, max and average values (±std) of key Nature Based Solutions (BR – bioretention, CW – constructed wetlands, BS – buffer strips, GR – green roof, PL – pearmeable layer, RWH – rainwater harvesting, S – swales) with depth (m), area ($m^2$), flow rate ($L\ s^{-1}$), nutrient and organic matter removal (%) and water retention (%). N.A. – not available.

| NBS | param | depth (cm) | Area ($m^2$) | Flow rate ($L\ s^{-1}$) | TN removal (%) | TP removal (%) | BOD removal (%) | TSS removal (%) | Water retention (%) |
|---|---|---|---|---|---|---|---|---|---|
| BR | min | 0.3 | 0.27 | 0.9 | -270.5 | -13.6 | 57.0 | -52.3 | 0.7 |
| BR | max | 200.0 | 81000.0 | 1.0 | 97.3 | 93.0 | 73.3 | 98.1 | 89.5 |
| BR | avg±std | 87.6 | 10397.6 | 1.0±0 | 9.9±78.4 | 65.5±28.6 | 67.4±9.0 | 65.5±49.3 | 53.0±30.8 |
| CW | min | 2.0 | 1.68 | 3.0 | -58.0 | -9.0 | 15.0 | -4.0 | 30.0 |
| CW | max | 120.0 | 4000000.0 | 3.0 | 97.0 | 96.0 | 90.0 | 96.0 | 88.0 |
| CW | avg±std | 69.2 | 207652.5 | 3.0 | 42.9±32.3 | 53.5±22.4 | 61.1±28.5 | 69.8±28.5 | 59.0±41.0 |
| BS | min | N.A. | 1.7 | N.A. | -94.0 | -212.0 | N.A. | -450.0 | 58.6 |
| BS | max | N.A. | 218.0 | N.A. | 51.1 | 46.7 | N.A. | 97.0 | 88.2 |
| BS | avg±std | N.A. | 63.7±80.6 | N.A. | -15.8±52.9 | -66.7±98.3 | N.A. | 42.3±125.6 | 65.1±12.9 |
| GR | min | 2.0 | 2 | N.A. | -40.6 | -247.6 | N.A. | 96.0 | 11.4 |
| GR | max | 40.0 | 2000.0 | N.A. | 87.0 | 93.8 | N.A. | 98.0 | 99.0 |
| GR | avg±std | 11.9±6.7 | 186.0±478.6 | N.A. | 27.2±44.0 | -51.1±136.5 | N.A. | 97.0±1.4 | 57.8±19.3 |
| PL | min | 8.0 | 18.0 | N.A. | 27.0 | 41.0 | N.A. | 91.0 | 29.7 |
| PL | max | 90.0 | 740.0 | N.A. | 91.0 | 98.0 | N.A. | 96.0 | 99.9 |
| PL | avg±std | 33.6 | 156.2±190.6 | N.A. | 62.0±26.7 | 71.3±28.7 | N.A. | 93.5±3.5 | 79.4±24.1 |
| RWH | min | 0.6 | 2.8 | N.A. | 6.0 | -110.6 | N.A. | N.A. | 53.0 |
| RWH | max | 122.0 | 4047.0 | N.A. | 68.0 | 68.0 | N.A. | N.A. | 98.8 |
| RWH | avg±std | 70.1±52.9 | 396.2±1060 | N.A. | 43.9±21.2 | 11.5±66.6 | N.A. | N.A. | 75.9±32.4 |
| S | min | 0.5 | 7.5 | 0.5 | -25.6 | -49.2 | N.A. | 44.1 | 33.0 |
| S | max | 130.0 | 130.0 | 8.4 | 85.6 | 68.7 | N.A. | 99.0 | 66.0 |
| S | avg±std | 19.1±44.9 | 52.4±57.2 | 1.7±3.0 | 41.7±42.4 | 9.0±44.2 | N.A. | 79.6±19.5 | 45.2±14.4 |