Moving Towards Water Resilient Communities

CONFERENCE PROCEEDINGS

6th Water Efficiency Conference

3-4 September 2020

Virtual Conference,
University of West of England, Bristol

watef

Conference of the Water Efficiency Network

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PREFACE

This is the 6th bi-annual water efficiency conference organised by the Water Efficiency Network. This conference is taking place during an unprecedented year where we are still experiencing natural and technological disasters, the SARS CoV pandemic, paradigm shifting social and democratic changes, and the ensuing economic challenges that all these brings.

Water is and remains a unifying factor for humanity. Primarily because we cannot survive without it. More so, that it holds the key to our environmental, social, and economic existence. With the Coronavirus pandemic, water has also been central and essential to the global health and social response. Maintaining good hand-washing hygiene and wholesome behaviour change remains one of the fundamental collective responses to the ongoing health crisis. However, this basic need, underpinning health and wellbeing-affirming action still eludes many. Therefore, the pandemic has taken hold to devastating consequences in many areas, including where basic access to water and sanitation is still lacking. This includes areas predominantly occupied by displaced persons, those residing in poor, informal and transitional built environments, and those living within unstable geo-political contexts.

These issues and challenges are directly or indirectly overwhelming, and do not need researchers, forecasters, or experts to state that the impact will be wide ranging and long lasting. For many people, the impacts are already here, and no one is immune to what some say is to come. Therefore, this network and other groups and networks continue to have important roles to play in proffering positive outlooks and solutions. Whilst maintaining a coherent message within ever-changing and conflicting priorities. We must, in whatever capacity and as the opportunities arise, continue to research, lobby, promote, motivate, and deliver on the importance of water, in its many forms, to people and society.

I make this plea, as the Water Efficiency Network rounds up its activities by February 2021. The network which has been in existence for almost a decade, started with the generousity and foresight of key people in the UK Government's Department for Environment, Food & Rural Affairs (DEFRA). Since then, we have collectively implemented research projects, organised and held events, seminars, workshops, study trips, produced technical reports, and produced multi-media materials for the public, informed policy and have supported water programs at the local, regional, national, and international scale.

We are comparatively a small network, but our work and message have been heard and applied worldwide. I am therefore immensely grateful to everyone who made this an impactful network. Your legacies in creating change and motivating action will endure.

I am also grateful to all the many past chairs, conference hosts, and participants of the Water Efficiency conferences. My thanks to Dr Sarah Ward and Prof Chad Staddon for positively rising to the challenges of hosting this year's conference. Thanks also to all the keynote speakers, special session conveners and participants, and all the technical authors and speakers that are contributing to the parallel sessions. Thanks to Eleanor Eaton, for all her effort in administering the network and this conference. This will be network's first entirely virtual conference, and I am sure you will agree that the program is truly forward looking, inclusive, and engaging.

I welcome everyone to this year's conference. May it be technical glitch-free, interesting, and rewarding. May the networking continue beyond these virtual 'walls'...

Water Efficiency Network Lead:

Dr Kemi Adeyeye
University of Bath, UK.

EDITORIAL

This volume presents a collection of papers selected for presentation at the 6th Water Efficiency Network Conference, focused on the theme of moving towards water resilient communities. The Watef Network aims to facilitate the promotion of water efficiency and sustainable water management in urban and built environments through knowledge exchange across academia, policy, and practice.

For 2020 the conference was supposed to take place at the University of the West of England, home to the Centre for Water, Communities and Resilience, at its Frenchay Campus in Bristol. However, the recent COVID-19 pandemic has meant that you are all joining us virtually, from your homes or offices, as large conference-scale gatherings are still not permitted under UK government guidance in a bid to keep the 'R-number' at around or less than 1, to 'Stay Alert, Control the Virus, Save Lives'.

In a very short space of time our home, work and leisure time and environments have changed beyond all recognition, with people doing things very differently to how they were at the start of the year. This has had implications for a number of sectors, with much focus on the NHS and keyworker roles such as supermarket staff, bus drivers and other roles that keep our society functioning. In the background our utility providers have been similarly working to ensure that the resources that support our everyday practices are still there, literally on tap, to help us reduce risk – hand washing has never been so far up the daily agenda in such a developed country.

During this conference we will touch briefly on the implications of COVID-19 for water, looking at recent trends, as this is also a question of resilience – are we resilient and resourceful enough as a society to respond to and undertake the level of change required to keep us going through and beyond a pandemic, for which there may not be a vaccine for at least 12-24 months? By exploring water poverty, social contracts, digital water and integrated management futures, as well as community responses, capacity building, knowledges, engagement, participation, innovation & integration for resilience in relation to social and environmental change, we will show the diversity of human responses that provide us with the faith that we can and will respond to the need for change in facing such an uncertain future.

We would like to thank the Local Organising Committee, Scientific Committee, Keynote, and technical session organisers and those who submitted abstracts and papers for supporting us in providing a comprehensive and exciting programme for the final WATEF Conference. We hope everyone enjoys and takes inspiration from the presentations, discussions and conversations that will be held over the next two half-days.

Conference Chairs:

Dr Sarah Ward
Prof Chad Staddon
University of the West of England UK

Jess Cook

National Energy Action

Jess Cook is Project Development Manager at National Energy Action and responsible for leading the 'People Living in Water Poverty and Fuel Poverty' work programme. This programme is funded by Northumbrian Water and aims to establish a formal definition of water poverty, understand the links between water poverty and fuel poverty and align policy and practical action to make a difference for customers struggling to pay, or at risk of struggling to pay, their energy and water bills. The final goal is eradicating water poverty in the UK by 2030.

Ian McGuffog

Bristol Water

Director of Strategy & Regulation Iain McGuffog took up the post of Director of Strategy and Regulation at Bristol Water and joined its Executive team in October 2017. Iain heads up the strategy and regulatory directorate and shapes the long-term strategy for Bristol Water as well as the PR19 business plan. With more than 15 years' sector experience, Iain joined Bristol Water from Ofwat, where he was Director, Strategy and Planning. Before this, Iain was Chief Economist at South West Water. Prior to the water sector, Iain built up experience as both a Management Accountant and Economist in the chemical, consumer electronics and rail sectors. He brings with him a wealth of experience and expertise in economic regulation, economic analysis, business planning and market strategy. Iain has an extensive track record of focusing on long term outcomes, including through three water price reviews, that balanced customer, investor, and stakeholder needs.

https://www.bristolwater.co.uk/iain-mcguffog/

Keynote conversation 1: Water Poverty and the Social Contract

Chair: Kathryn Rathouse

In this keynote session Jess Cook from NEA and Iain McGuffog from Bristol Water will discuss water poverty as an issue connected with water labelling, water metering, water efficiency and the hydro-social contract in general. They will explore how reducing water poverty is contingent on integrated perspectives, programmes, and policies across the water sector and beyond. The session aims to bring a range of perspectives from inside and outside the water sector, including consumer organisations, organisations working with customers with affordability issues, and the energy sector.

Professor Chad Staddon

Professor of Resource Economics and Policy, University of the West of England

Prof Chad Staddon is Professor of Resource Economics and Policy at UWE, Bristol and founder-director of the International Water Security Network. In the course of his 20 year career he has studied water services in Canada, the US, the UK and many European countries. He has published more than 40 scientific papers and books, given more than 100 public lectures and is frequently called upon to comment on relevant government policy. His current research interests lie in the area of better understanding the nature and drivers of urban water demand and the potential for social and economic instruments to drive conservation efforts.
http://www.watersecuritynetwork.org/people/chad-staddon/

Keynote conversation 2: New trends in high frequency water demand monitorization and analysis: experiences and challenges

In a presentation of two halves, Chad will take us on a global journey considering the impact of COVID-19 on handwashing & Sustainable Development Goal 6 and water use distribution & patterns of consumption: and implications of research into COVID persistence in wastewater.

SPECIAL SESSIONS:

Claire Hoolohan

University of Manchester, UK

Claire is a Presidential Research Fellow at the Tyndall Centre for Climate Change Research, University of Manchester, specialising in sustainable consumption, food systems, water demand management and climate change mitigation. Her research examines the connections between consumption and whole systems, to understand opportunities for sustainable futures and she collaborates with businesses and policymakers to support sustainability transitions.

https://tyndall.ac.uk/people/claire-hoolohan

Digital Water Futures Dialogue

Chair: Sarah Ward

Lead author on a recently submitted, state-of-the-art journal paper on re-socialising digital water transformations, Claire will guide us in an interactive session exploring a range of perspectives on this emerging and challenging area, which requires us all to reflect on the nature of our digital interactions.

Water Reuse Technical Committee, WATEF NETWORK

Lutz Johnen

Aquality

Lutz has 20 years of experience with rainwater & greywater systems and was Export manager and director of a German systems manufacturer for 10 years before moving to London and founding Aquality. He is a Member of the British Standard Committee for rainwater harvesting & greywater recycling. Currently representing the UK on the European Standard for the same subject. He was Chairman of UKRHA (UK Rainwater Harvesting Association) for 3 years and Member of UKRHA, Fbr (German rainwater association) and ARCSA (US rainwater association) as well as IFEP (French rainwater association). His specialties are consulting on non-potable water management; design, supply and service of rainwater harvesting, greywater, cooling tower water recycling systems; and combination with attenuation, soak away systems and similar.

Lydia Makin

Waterwise

Lydia is Policy and Projects Manager at Waterwise. She previously held the role of Water Efficiency Supervisor at Welsh Water and is a graduate of Welsh Water's Operational Management Graduate Scheme. She has a First-Class Degree in BSc Environment and International Development from the London School of Economics and is Prince 2 and ILM Level 3 Qualified.

Peter Henley

WRC

Peter is an experienced technical specialist in buried assets, busy identifying and developing new and exciting techniques to undertake condition assessment, maintain and repair pipelines to provide clients with significant operational and capital cost savings.

Mike Farnsworth

Stormsaver

CEO of Stormsaver Ltd, Michael Farnsworth is well renowned in the rainwater harvesting industry, having designed the first UK manufactured rainwater harvesting solution. Over the last decade and a half, he has pioneered new concepts, ground-breaking designs and developed a passion for water conservation. Together with the Stormsaver team, Michael has been passionate about raising money for the Company's chosen charity, WaterAid.

Resilience and Integrated water management: A call to action

The subject of water resilient cities has become ever more important after worldwide drought and especially near miss of the day zero in Cape Town. But resilience regarding flooding aspects is equally important in the UK. Therefore, integrated water management is a key component combining water reuse technologies with Sustainable Urban Drainage methods (SUDs). Water reuse covers technologies such as rainwater harvesting and greywater recycling. These can play an important role in SUDs to reduce the volume of water in combined sewer systems that are already not able to cope with larger rainfall events in many cities. This thought provoking, interactive session will explore the different contexts in the UK. We will ask why isn't more happening to improve water reuse in the UK, and what could a creative solution look like? Four panellists will give their views in lightning style presentations, followed by a live discussion with members of the audience. The aim of this session is to create a clear call to action for policy makers.

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Water Efficiency Network

Proceedings

#1. Community responses & capacity building for environmental change

Allotments in the Future

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ABSTRACT

In recent years there has been resurgence in the popularity of allotments and home-grown food in the UK. This interest is likely to increase as people become more aware of the health benefits of spending time outdoors.

The UK Climate Projections (UKCP2018) indicate that over the next 10-20 years winters are likely to become warmer and wetter and the summers hotter and drier. The Drought Risk and You (DRY) project has been working with The National Allotment Society (NSALG) https://www.nsalg.org.uk/ to explore how people use water on their allotments and in their gardens to help share examples of good practises so that growers can adapt to the changing climate. Encouraging individuals to collect and use rainwater efficiently was identified as one of the key areas.

Most UK allotments and community gardens are organised as a group of individual plots of approx. 250 square metres. Each plot holder manages their own plot as they wish, within site rules. Some sites have mains water provided, however the amount available can be limited creating tensions. The NSALG has been trying to encourage plot holders to use mainly rainwater. However, individual efforts to collect and store rainwater can often be limited by site rules restricting the size or number of structures.

We explore an innovative approach to allotment design to enable allotment growers to maximise potential for rainwater collection and improve the efficiency of water use and thus adapt effectively to a changing climate.

Keywords: Allotment, water efficiency, climate change

1. INTRODUCTION

Allotment gardening has a long history in the UK and has gone in and out of popularity over the last 250 years. Allotments were initially created in response to social unrest among rural labourers who had been left with nowhere to grow food for their families following the enclosure of common fields in the 1700 and 1800s. The importance of allotments and private gardens in producing food during both the First and Second World Wars when 1,500,000 plots produced over 20 million tons of food is well known [1]. Since the Allotment Acts of 1887, 1890, 1907 and 1908 local authorities have had an obligation to ascertain demand and provide sites for allotments. The 1925 Allotment Act stated that land purchased by councils

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specifically, for allotments cannot be sold or converted to other uses without ministerial consent (a Section 8 Order) [2]. However, post 1960, an overall decline in the popularity of vegetable growing, combined with pressure for land within or on the outskirts of settlements for housing and business development, lead many private owners, such as the Church or England and British Rail, as well as some local authorities to sell off sites [1].

Over the last 25 years there has been resurgence in the popularity of allotments and home-grown food in the UK. There are many factors behind this resurgence including concerns over the environmental costs of food transport and packaging [3] and the use of chemicals in food production, an interest in fresh home-grown produce [4] and awareness of the physical. Mental and social benefits of being out of doors [5] and desire to become part of a community [6].

In 1996, in UK, there was an average of 4 people waiting for every 100 plots but by 2012 around 87,000 people were on waiting lists for just over 152,000 statutory plots managed by principal local authorities, the equivalent of 57 people waiting for every 100 plots [7].

At a more local level, in Bristol alone there are 112 allotment sites of which 93 are owned or administered by Bristol City Council. These 93 sites comprise 3920 plots, and in March 2020 there were 521 vacant plots and 5083 people on waiting lists. Bristol City Council's Allotment Strategy mission statement (2018) [8] is 'To work towards the vision of a sustainable Bristol through maximising the participation of its citizens in allotment gardening by the improvement of allotment sites and their management, and through the promotion of the benefits and enjoyment of allotments and food growing.' It is a requirement of the Allotments Acts 1908 that an allotment authority must consider providing allotments where there are 6 people or more requesting to rent allotments [1]. However the Bristol City councils own strategy document (2018 [8]) states that 'Further surplus land is likely to be declared surplus over the next ten years unless demand increases significantly on those sites, whilst some are likely to remain as open space for the foreseeable future' , reflecting the fact that demand and supply are not always in the same location.

There are many different types / models of allotment sites and community garden. Ranging from semi-commercial scale schemes, such as the Sims Hill shared Harvest group in Bristol [9] where there is a 'farm manager' who coordinates activities on the site, and members volunteer to help in return for part of the crop with the remainder of the crop being sold, to garden squares [10] and small community flower beds that may only be a few meters square. However, the traditional allotment garden usually consists of a number of 250 m^2 plots, often laid out in more or less straight rows.

Some sites have water supplied direct from the mains while others rely on incident or collected rainwater. Even when mains water is included in the rent charged for an allotment plot the amount is usually limited and there can be tensions between people who use little water and those perceived as using more than their fair share. The number of water trough or taps are usually limited and people whose plots are some distant from the tap may have difficulty carrying water to their plot. Some sites allow plot holders to put up a shed while a few have a communal hut and even fewer a toilet. The NSALG has for many years been encouraging plot holders to (predominantly) use rainwater, and many growers consider that rainwater is better for plants than tap water [11].

As part of the Drought Risk and You (DRY) project we have been speaking to members of the NSALG, allotment groups and professional horticulturalists to develop a greater understanding of water use on allotments and for growing crops. There is a great deal of published information and guidance for growers and community garden groups on which plants to grow in different situations and the most effective way to utilise available water from all of the gardening organisations in the UK and the government [7, 11]. Watering and water availability were an important concern for all the people that we spoke to. This highlights the importance of collecting, storing and using water effectively to ensure an adequate supply of water throughout the growing season

The UK climate change projections (UKCP2009 and 2018) predict that within the next twenty to thirty years the UK will experience warmer and wetter winters and hotter drier summers [12] Computer modelling for the catchment of the River Frome, conducted as part of the Drought Risk and You (DRY) project indicated that in the Bristol region by 2050 we could expect 2.8 - 3 ^{o}C rise in summer temperatures and a rainfall deficit of 19.8 - 20 mm compared to the 1961 - 1990 average [13]. Higher summer temperatures will increase the amount of water lost by evaporation and evapotranspiration, and is likely to increase human demand for water. The reduction in summer rainfall is likely to further increase pressure on existing water supplies not just for gardening but also for public water supply and recreation. This reinforces the importance of collecting and storing water during the winter when for the UK rainfall normally exceeds water use or during periods of high rainfall in summer.

The way in which allotment sites are traditionally arranged and managed does not always support this, because water storage and water use efficiency is a secondary concern when the sites are created. We have considered how an allotment site could be organised if water is placed at the centre of the design.

2. THE ALLOTMENT OF THE FUTURE

More efficient use of water in a garden or allotment can be achieved in several different and complimentary ways: rainwater collection and storage, site layout to minimise run-off and improve water infiltration, cultivation methods to improve soil water holding capacity, choosing plants that need less water, improving watering efficiency.

Rainwater Storage and collection

On most allotment sites plots are managed individually, rainwater collection is at the discretion of the individual plot holder and on some sites this may not be possible because of local rules that prevent plot holders erecting permanent structures. Members of the NSALG have shared with us many of the inventive ways they have found to collect and store water [11]. However there is a limit to the amount of water that an individual can collect and store and concerns have been raised about the environmental cost of multiple plastic water butts [11]. It is more efficient to collect water and store it on a larger scale, either as a centralised site water collection and storage facility or using a semi- distributed system where neighbouring plot holders share water. Our analysis suggested that for most allotment sites a semi-distributed rainwater collection and storage system would be the most practical because it would increase the amount of water that could be stored and minimise the distance between source of water and site of use. At the same time it would encourage neighbours to cooperate with each other and this would encourage plot holders to develop a sense of place and responsibility/ownership. Although nothing would prevent a selfish individual from using more water than their neighbours because the number of plot holders sharing a common water source is small those individuals would be easily identified. It would also mean that all plot holders were close to a source of water so that people who could not easily carry watering cans would not be disadvantaged. During the winter when rainfall normally exceeds demand for water the excess could be diverted to the lowest part of the site, perhaps to an area that typically is wetter and more prone to waterlogging to create either a small pond or bog garden that would contain a variety of flowering plants such as water mint (*Metha aquatic*) or yellow flag irises (*Iris pseudacorus*) that would help to encourage pollinating insects but that can tolerate drier conditions in the summer.

Site layout

Few allotment sites are completely flat or uniformly well drained. Regularly used paths inevitably become compacted, and water does not infiltrate into the soil easily. Ideally permanent paths should be laid out following the contours of the site. This will reduce runoff during periods of intense rainfall (rainfall intensity is predicted to increase in the near future) and encourage infiltration into the soil since the compacted area of soil under the path will act as a barrier to through-flow in the surface layers of the soil. If there is an area that tends to be wetter than others this is the ideal place to site a wildlife area with either a small pond or bog garden. An area dedicated to wildlife will help to encourage pollinators and increase biodiversity. This is also beneficial to animals such as hedgehogs, frogs and toads that eat many of the invertebrates that are considered to be pests on allotments such as slugs and snails. Just as scale offers benefits in terms of efficiency of water collection so does site delivery of compost or manure. Ideally there should be a central area where bulky material such as manure can be delivered, and if possible this should be accessible via a paved or concrete track. Not all allotment gardeners will need or want a full sized plot for many people half or even a quarter plot may be plenty and the site should have some areas with smaller plots. Similarly people with mobility problems, whether due to illness, age or young children, may not be able to easily tend a conventional plot. Natural England estimates that 42% of population have some mobility problems [14]. These people may prefer to have raised beds or planters and these should ideally be located on a path than is level or on a gentle gradient that can be used by wheelchairs, prams and preferable close to the site entrance so that they can drive to the site if needed. If there is a communal site hut, rainwater could be collected from the roof for use on these smaller areas. Few traditional allotment sites have a communal hut but those that do have shown that it can be an important social focus as a place where people can swap seeds, plants and produce [11] as well as providing a secure storage area of group equipment such as a mower or strimmer. If the communal hut is well planned it might be possible for individuals to have a locker to keep a few tools. There should also ideally be a composting toilet, again located close to the entrance and site hut, as this will make the site more attractive, particularly to people with families. A rota for maintenance and costs could be included in the site rent.

Cultivation and within plot layout

Soil structure is important for drainage, water holding and mineralisation of nutrients all of which are critical for plant establishment and growth.

In recent years the ‘no dig’ approach [11, 15] has become popular, and if followed is very successful in controlling weeds and pests while at the same time improving soil structure. Central to the success of the no dig approach is the setting up of permanent beds surrounded by paths. Even if no dig is not followed it is a good idea to set up permanent beds so that most traffic, and associated soil compaction, is confined to specific areas and the soil structure on the growing areas improves. Permanent beds need not mean having permanent structures, with the associated maintenance and cost; in fact Charles Dowling one of UK leading proponents of ‘no dig’ suggests that once beds have been established it is better not to have wooden boards lining the plots as these provide hiding places for slugs and snails.
Having more paths, will mean that the area available for cropping is reduced, however studies of allotments have shown that it is unusual for all the available area to be used for crops. A study of allotments in Leicester [16] found that on average cultivation of fruit and vegetables

used 51% of the available area, with hard surfacing, permanent structures ,compost heaps , fruit trees and flowers bringing the used area up to 67-70% leaving around 30% of the available ground uncultivated. Thus losing a few percent of the available area to wider and better paths would have negligible effect on the area used and in fact by improving accessibility might actually increase the amount of ground under cultivation.

Planting to make optimum use of available water

Gardeners have an enormous choice of possible plants that they can grow in the UK, and the variety of crops grown by gardeners is increasing as the ethnic range of the population increases and people want to try crops that they have seen whilst visiting other countries. Whilst working on the DRY project many growers and gardening organisations shared with us their advice on the best crops to grow to make use of the available water.

In general plants that can be sown during the autumn and that develop their root system during the winter will be in the strongest position when making optimum use of available water because they will be growing and using water at the time of year when rainfall exceeds water use. Corn salad, land cress and oriental salad leaves (such as komatsuna, mibuna, mizuna, mustard and rocket).will provide leaves through the autumn, and winter if sown in early autumn while the soil is warm and covered with a cloche, cold frame or fleece.

Autumn sown broad beans, Swiss chard, kale, spring cabbage, chicory produce an early crop (late spring/early summer) when vegetables in the shops are expensive. Perennial plants, such as asparagus and rhubarb or perennial varieties of crops usually grown as annuals such as Swiss chard, kale, globe artichokes or welsh onions are also able to make use of water early in the growing season, when other vegetable crops may be in short supply and expensive.

Some varieties are more drought resistant than others. For example, Cos lettuce requires less water than cabbage lettuce (such as Iceberg or Webs Wonderful). ‘Cut-and-come again’ salad leaves (like Lollo Rosso) require less water than soft lettuce (such as Little Gems).

Improving efficiency of water use.

During hot dry spells watering can be a time-consuming task for gardeners however by using water in the most efficient way the time and amount of water needed can be dramatically reduced. Efficient water use is important at every stage of plant growth. When planting seeds, as many experienced gardeners will tell you, if you water the drill before putting the seeds in you are ensuring that the seeds are being paced in the optimum conditions for germination. If you water after you have planted the seeds some seeds are likely to be sheltered from water by stones or other debris in the soil. The increase in humidity in the soil compared to ~~in~~ the seed packet will trigger the seed to begin germination. The developing seedling will start to respire using up energy stored in the seed, but there must be sufficient water available to completely hydrate the seed to allow the developing cells to expand and encourage the seedling to grow. Once seedlings have germinated watering should aim to encourage the development of strong deep roots, the best way to do this is to water close to the base of the plant and rather than sprinkling every day, which encourages roots to develop at the surface where they can quickly dry out to give less frequent more thorough soakings. The practical use of trickle irrigation which provides a slow gentle supply of water to the roots is most effective. Mulching also helps to increase the efficiency of water use because it reduces the loss of water from the soil surface by evaporation while at the same time promoting the development~~s~~ of good soil structure. Grouping plants by water needs also ensures that water is used most efficiently. Thus leafy crops like spinach, lettuce, rocket, and plants very sensitive water stress such as tomatoes could be grouped together, close to the water supply and crops that will grow without much added water such as potatoes, sprouts and leeks could be further away.

3. CONCLUSION

We envisage an allotment site with a range of different sizes of plots, arranged in groups of 4-6 around a shared water collection point, this could be incorporated into some type of awning and bench. Excess rainwater could be led, perhaps via French drains to a boggy area or pond that formed a focus for wildlife. The plots would be separated by well-maintained paths that were wide enough to allow wheelbarrow or wheelchair movements, and which followed the contours of the site. Groups of plots would be separated by a made up paths coming from a central hardstanding. The hardstanding would be the site of a communal hut and toilet, drop off area for bulky materials like compost and also be surrounded by a mixture of raised planters and small beds suitable for wheel chair users or other with limited mobility. Some of the smaller plots could be dedicated to flowers to encourage pollinators. Also close to this central area would be an area where children could play.

This design would encourage a wide mix of different people, the grouping of facilities into things shared by a few people would help to promote neighbourliness and sense of place and deter selfish behaviours. By making the site attractive to families and disabled people it would likely be used for more of the time and this would help to deter vandalism. These benefits would be on top of the already demonstrated benefit of allotment gardening in reducing food waste, encouraging a varied diet with fruit and vegetables and improving physical and mental health.

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COMPETING INTERESTS

The authors have no competing interests.

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Promoting water efficiency and hydrocitizenship in children's learning for resilience about drought risk in a temperate maritime country

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ABSTRACT

This paper outlines the development process and evaluation of a new primary school book *DRY: Diary of a Water Hero*. The book's development was underpinned by research within the NERC DRY (Drought Risk and You) and About Drought projects, forming part of a multi-stakeholder knowledge exchange programme. The story book, its concept and storyline were co-produced by an interdisciplinary and inter-professional team including a creative practitioner. The book focused on exploring key themes, emergent from research with different publics:

- What is drought in a temperate maritime country like the UK?
- What are the different types of drought and how are they manifested?
- What are the myths about UK Drought identified in the DRY project, and how can they be explored, challenged and countered? These include: 'water is infinite and free'; 'Britain is wet: droughts don't happen'; 'droughts only happen in summer, when it's hot'.
- What are the possible drought adaptations at household/community levels?
- What drought actions might people do - focusing on civil agency and children as change agents?

Characters and story line were carefully considered in order to promote children's agency and encourage inter-generational and community learning. The book has been exchanged nationally as hard and e-copy in English/Welsh, along with teachers' notes. This paper then shares learning from preliminary evaluation of the book with children and teachers, and reflects on how these insights might feed into practice about the development of learning resources to promote water efficiency, hydrocitizenship and behaviour change among children, and then the wider community.

Keywords: drought, resilience, water behaviours, citizenship, agency, adaptation

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1. INTRODUCTION

Over the past five years, UK Research Councils have co-funded innovative, interdisciplinary research into the UK's past, present and future drought risk and its impacts, with an aim to step-change the evidence base to support decision-making. As part of ensuring that all sectors of communities are engaged in knowledge exchange from the research, the DRY (Drought Risk and You) project worked collaboratively with a socially engaged artist and two specialist teacher trainers to create a thought-provoking narrative within a 'learning resource' that would engage primary school children at Key Stage 2 (7-11 years). There is growing interest in the role of children as eco- or hydro-citizens (Williams and McEwen, 2017; McEwen et al., 2020); this framing considers personal reflection on self, relationships with others and environment, through the lens of water. This extended abstract shares some critical considerations with regard to our processes in developing the book and teacher's notes, and signposts the actual resources that are available for sharing widely.

1.1 Background contexts

Here we briefly consider three contexts to the development of the book: UK drought as a hidden risk; the Primary National Curriculum and the st(age) of children's learning.

<u>1.1.1 Drought as a risk</u>

Drought in the UK is a slow, diffuse, hidden and uncertain risk, involving multiple stakeholders including different publics. The 'drought' word is rarely used by statutory authorities (water companies; environmental regulators) because it is perceived as highly politicised. Public perceptions of drought as a risk are reinforced by the media, with weather reporters tending to refer to positive elements of extended heat and lack of rain. Drought memories and stories of extreme drought do not tend to circulate in local communities. Memories of the impacts of the 1975/76 drought, the most extreme in living memory, sit with a specific generation now in their 60s. These can be of the halcyon days of youth, hot summers and sitting listening to Abba. Overtime, memories become stories and may retain fragmented, interpretative information which can serve to provide inter-generational context and discussions. The DRY project needed to dig deeper to find adult memories of challenge: of running households, businesses and farms during full blown socio-economic drought when water does not come from the tap and different users are prioritised. The DRY project has worked to address this, bringing local knowledge of past drought alongside the science of drought. Working in seven case-study catchments across the UK, the DRY project found misleading 'drought myths' in general circulation that need challenging'. These include ideas that 'water is infinite and free', that 'Britain is wet and droughts don't happen' and 'that drought only occurs in summer when it is hot'. In response to this, we made understanding the language of drought' and 'myth busting' as aspirations for the book.

<u>1.1.2 The Primary National Curriculum</u>

The children in our classrooms are frequently bombarded with doom and gloom stories about the state of the world: food poverty, war, carbon emissions, climate crises water shortage - all which can cause increased eco-anxiety amongst children. Hicks (2018) and Whitehouse (2018) remind us that teachers should not dwell on these negative stories as this can support and develop a sense of despair, and powerlessness for our pupils in the face of global political landscapes. This positions the children as passive recipients of information rather than active problem solvers. Instead, we need to embrace pedagogies that will support young people to feel empowered to act as global citizens, and begin to make steps to create the future they want. Hicks (2014) refers to the pedagogies that support this as a *geography of hope*; one in which crises are not just reported in our classrooms, but carefully planned pedagogies are used to support the possibility of behaviour change at a local level. This is in order to build global understandings, and young people's agency for long term sustainable stewardship.

Hicks (2019) has outlined four critical stages that educators can use to frame effective engagement with global crises. We should support:

1. the acquisition of appropriate knowledge of the issues
2. an exploration of young people's feeling towards these issues
3. the identification of relevant choices for positive change
4. opportunities to engage in appropriate action for change

In this children's book and accompanying teacher's notes, we show how this four-staged approach can be facilitated, and the challenges and opportunities that may result on the journey.

1.1.3 St(age) of children's learning

The st(age) at when to introduce children to topics such as drought caused by environmental changes as a result of climate changes is not well understood and can be contentious. This leads to some believing that children should not learn about or be involved in these issues, in turn meaning they become excluded from decisions and policies that affect them. This positions children without agency. The decisions surrounding the inclusion of these topics in both formal and informal educational settings needs to be considered from a number of angles, including developmental (cognitive skills and understandings) and socio-emotional. The 'water cycle' is in the primary geography curriculum, as is how we use 'resources' of which water could be considered one. However, there is little explicit guidance on drought, water scarcity and climate change for teachers within the curriculum. Despite this, young children have shown their interest in, and concern about environmental changes, climate change and sustainable futures evident through the global climate marches (Greta Thunberg). Here they are clearly indicating that they want a more active part in the debates and actions that are focused on more sustainable futures.

In order to include children and facilitate their learning about drought, teachers and those involved in children's education need high quality, research informed resources that can provide a framework for the introduction of topics such as drought in a st(age) appropriate way. Cognitive development of processes, such as learning and memory as well as attitudes and value formation, take place throughout childhood, and at the ages of 7-11 children are becoming more refined and empathetic in their understanding. This could be the ideal age at which to focus educational resources in relation to droughts (and other environmental issues) to encourage future resilience.

2. METHODOLOGY

2.1 The book's thematic focus

The development of the primary school book, *DRY: Diary of a Water Super Hero,* was underpinned by research within the DRY project. In particular, we focused on four themes:

- Classifying UK droughts and identifying their impacts: This involved exploring 'what is drought', recognising that drought means different things to different people depending on its impacts on humans and non-humans – both wild and companion animals. The book explores the different types of drought, e.g. rainfall drought; soil moisture drought; river drought; water supply drought, and how they might manifest themselves locally.

- Interrogating common misconceptions surrounding UK drought: The book takes the pervasive myths about UK drought and water availability and challenges them.

- Exploring what actions citizens might take to prepare for drought: This explores how children can be change agents in rethinking water behaviours, and asks about the possible adaptations to drought. These might include saving water, storing water, thinking about water stored in food (hidden or embedded water), and the differences between directed actions and changes in social norms.

- What actions citizens might take in relation to drought: The book explores civil agency (citizen action) and how children might act as change agents in their families and communities, with an inclusion of inter-generational learning.

2.2 The development process

The story book, its concept and storyline were co-produced over a period of nine months by academic researchers in water risk management and environmental psychology of children, a socially-engaged artist, and two Primary Education specialists. The illustrations were co-developed by Luci Gorell Barnes - as an integral part of that co-authoring process. The development of the accompanying teacher's notes aimed to support the book's use by varied educators. This expertise combined to provide a unique skill set for the book's development, combined with preliminary work like a content analysis of the UK primary curriculum.

The storyline of the book, written as a young girl's diary, runs monthly over the course of a year. It tells how an ordinary schoolgirl in the UK transforms into a water superhero when a dry summer and winter with little rainfall lead to drought. Seeing life through 'water goggles', the girl shares her new-found understanding and respect for water with her family. On her stimulus, they start to change their lifestyle habits. She then works to share this love and understanding of water with her school and community, as the drought progresses. Throughout, we tried to choose actions that young people could do themselves in order to emphasise the message of personal agency.

The book is designed with children's cognitive st(age) in mind, and constructing them as agents of change. Consideration is given to the overall messaging in terms of empowering children to act, intergenerational learning and influence, vocabulary, mathematical abilities and contained within the overall contextual research findings about drought. The co-authoring process involved five creative meetings that were audio-recorded, along with virtual exchanges of ideas and drafts.

3. RESULTS AND DISCUSSION

3.1 Evaluation and feedback

The draft books were tested using participatory methods with primary school children and teachers in two Bristol schools, and were also informally tested with parents and children. Both book and teacher's notes have been used in schools alongside participatory methods, with feedback from pupils and teachers informing revisions.

The young people said:

"There are lots of ideas in the story on how to save water."

"I'd never really thought that the UK could have a drought… I've learned a lot."

"The activities were fun and interesting."

Teachers commented:

“This book and associated activities has really made me think about how I use water and I know it’s a resource I’ll be using again and again.”

“A great story that supports geography and science topics.”

3.2 Interdisciplinary reflections

We now reflect on the impact, originality, quality and usability of the DRY Primary Book, following multi-stakeholder interest at its launch at the ‘About Drought Download event at the Royal Society, London in November 2019. This learning resource forms a unique part of knowledge exchange about UK drought, targeting children as young citizens with agency. With climate crises and increased eco-anxiety amongst children, this resource provides teachers with a tool to support understanding the complex issues surrounding the often hidden risk of drought in the UK. Through the narrative, visual clues and activities, the resource explores how children can be key hydrocitizens and influencers at home and in the community.

The book’s originality comes from content and approach. It draws on research linking different kinds of ‘evidence’ - science and stories from seven river catchments across the UK - alongside cross-disciplinary expertise. The challenge was to make research accessible to children, and to unpick visually the four themes identified and explored in the resource in ways that engage. In doing this, we deliberately interwove the narrative with thought-provoking facts. In promoting usability, layered illustrations and notes were developed to act as stimuli for discussion, and to promote thinking around individual and collective agency. Chawla and Flanders-Cushing (2007) talk about how action for the environment often looks at private behavour change (for children). They argue that solutions need to be multifaceted, and combined with actions for collective public change. The book looks at both the personal and community sphere.

In terms of physical character, we paid attention the size of book and print quality, recognising this has a large impact on appeal to children. We continue to run an evaluative survey to gain understanding about how the resources are being used, and their impacts on supporting curriculum design and teacher subject knowledge. We ask for assistance in sharing the book resource around different stakeholder networks, and very much welcome feedback.

4. CONCLUSION

We conclude by sharing how you can access these resources. All are free and available online at: https://dryutility.info/learning, with a short run of hardcopy. The book is available in English and Welsh. The teacher’s notes are available in English, and have been edited into Welsh by Natural Resources Wales. Hardcopy of the book for educational use can be obtained by emailing: dry@uwe.ac.uk. Educators are encouraged to complete a short online questionnaire about their experience of using the resources (also available at dryutility.info/learning). The book received a Silver Publisher’s award for merit from the Geographical Association (spring 2020).

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COMPETING INTERESTS

The authors have no competing interests to declare.

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Evaluation of a social-environmental approach for disaster risk management

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ABSTRACT

Recently, bottom-up and horizontal approaches are being promoted as methods for disasters management, where the link between "environmental" (e.g. physical) and "social" indicators (e.g. demographic and "exposure" to disasters) is suggested as components for risk assessments. Despite the recognition that effective disaster management must integrate the social and environmental sciences, such integration in practice is still relatively rare. Their application faces many barriers due to data availability, legislation arrangements, time constraints, stakeholder's engagement, and citizens awareness. With this regard, this research contributes to this context by developing and evaluating a socio-environmental approach for flooding and water shortage management in a middle-sized city, Campina Grande - PB, semiarid region of Brazil. The approach used a mixed-method framework, with both objective and subjective methods, where approximately 200 different stakeholders were involved, with questionnaires, presence in focus groups and workshop. The PLANEJEEE Project: To Plan Extreme Events (from Portuguese: *"Planeje Eventos Extremos"*) had the goal to identify key challenges and solutions to the water-related hazards management, including barriers to the co-production of knowledge, volunteer participation and trust. Conclusions highlight the importance of integrating social and environmental sciences to effective water management. In presenting our analysis, our objective is to inform policymakers and contribute to achieving a better understanding of the current context and proposing alternatives for adaptation and mitigation of water-related hazards along with stakeholder's engagement.

Keywords: disasters management; social and environmental sciences; stakeholders' engagement.

1. INTRODUCTION

In recent years, a combination of urban development and changes in climate have increasing population exposure to higher temperatures and rainfall variations. This context leads to changes in land use and compromises the well-being of urban inhabitants. The semiarid region of Brazil combines two water-related disasters. From 2012 to 2019, the region faced one of the most extended and severe droughts in history [1]. Between the years of 2012 and 2013, more of 1300 municipalities and approximately ten millions of people were affected. According to

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data from the National Institute of Semiarid (INSA) in 2017, only 17% of superficial water was available in the reservoirs [2]. However, within the region, many cities face flooding cases [3]. This situation suggests a dual-disasters context, with severe gaps in management and reduction of quality of life. Semiarid projects are challenged to search for living alternatives to extreme climate events and the creation of social improvements [4].

This complex context asks for better cooperation in the management, with an integration of all systems, sectors and parameters that interferes in cities. Following the guidelines, the drainage systems should be upgraded to handle extreme climate conditions, prevent disaster events and support an integrated approach for urban planning and develop strategies for mitigation of extreme conditions. The complex system is characterised by a range of attributes (e.g. vulnerability), which is composed of weaknesses (e.g. sensitivity) and strengths (e.g. capacity). In this study, we will consider the vulnerability to disaster as the *"manifestation in a series of categories that do not develop independently but interact on many different time and space scales"* [5]. From environmental science, the system is also characterised by the exposed elements to a hazard (exposure). We argue that both system attributes and exposed elements are directly related to a specific event; hence we call them "hazard-specific components". Their relationship shows an anticipatory state or "pre-existing state" concerning the hazard. Along with the hazard occurrence, both vulnerability and exposure will produce impacts, which can be increased or decreased by adaptation/mitigation strategies (Figure 1).

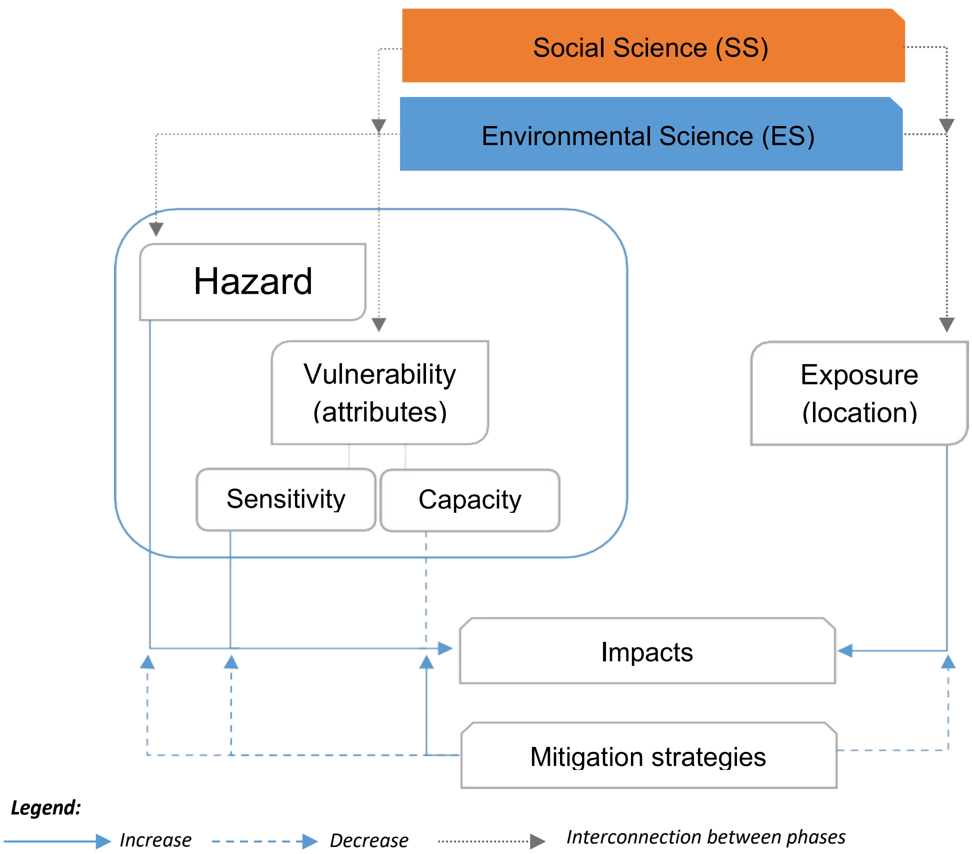

Fig. 1. Construction of a socio-environmental approach

Integrated planning should include parameters of physical, microclimatic and occupational aspects as well as different stakeholders to propose a context-based approach to mitigate impacts of extreme events. Integrated planning is the foundation of the development of measures to improve the environment [6] and is promoted by Integrated Water Resources Management (IWRM) [7]. For the past two decades, IWRM has been considered the dominant paradigm in water resources management. The "integrated approach" aims to improve water governance with full participation in decision-making process and is currently applied internationally [8]. This includes the establishment of an overall water policy and laws which use the catchment as the scale of management [9], considers all types of resources and incorporates the elements of good governance [7]. The use of an integrated approach with water resources following environmental and sustainability objectives help to avoid conflicts related to water management [10] and is essential for achieving sustainable development including social and economic development, poverty reduction and equity, and sustainable environmental services [8].

However, to date, a limited number of integrated systems have been developed to analyse floods and water shortage mitigation in semiarid regions. We suggest that individuals and communities are differently exposed and vulnerable to hazards, based on inequalities and structures of the region. This makes essential to understand the multi-faced nature of environmental and social sciences for determining how extreme weather events contribute to the occurrence of disasters and for implementing effective adaptation and disaster risk management strategies.

To obtain data from both environmental and social sciences, we developed and applied a participatory approach in Campina Grande, semiarid region of Brazil. This paper summarises some of the findings obtained with the collaboration of 199 stakeholders from May to June of 2019. We believe these findings can be helpful for other cities facing challenges with dual water-related hazards and contribute to the discussion of integrating environmental and social sciences in similar studies.

2. STUDY CASE

Campina Grande is located in the Brazilian semiarid (Figure 2a) and is the second-largest city of Paraiba State. According to the Brazilian Institute of Statistics and Geography (IBGE) [11], the city has 410.332 residents and 594.182 km² of territorial area. From 1991 to 2010, the urban population increased more than 20%, representing many changes, such as the number of paved streets, buildings, etc. The urban growth and interventions in the natural environment have several impacts on the hydrological cycle in urban environments, namely: increased soil imperviousness and, consequently, increased surface runoff volume. The city is also considered the second most urbanised in Paraiba State [11], have regular floods cases [3] with short recurrence times of rainfall and drought as climate [12].

The city does not have official flooding or water shortage maps to guide water management. For flooding, the Geological Survey of Brazil (CPRM), in 2013, mapped ten formal risk areas which are used for urban and planning purposes (Figure 2b). To guide the water rationing, the city is split into two operational zones, and each spends some days in a week without tap water (the number will depend on the water shortage intensity). For the water shortage, the entire city is included in the water rationing.

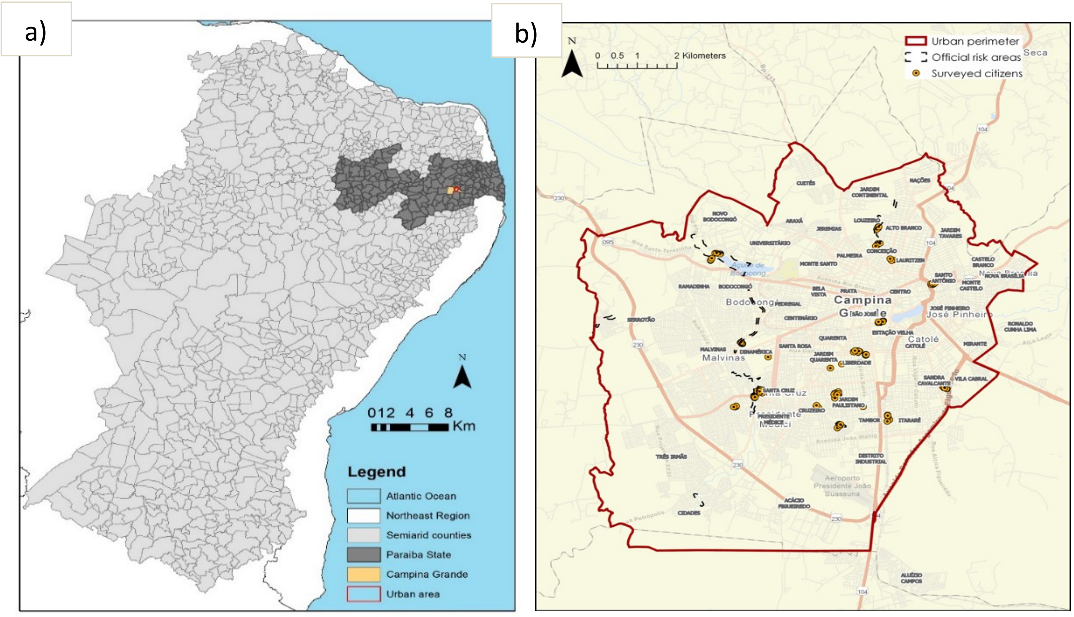

Fig. 2. a) Location of Campina Grande in Brazilian semiarid; b) Urban area of Campina Grande and official flooding risk areas

3. THE PARTICIPATORY APPROACH

The Project PLANEJEEE: To Plan Extreme Events ("Planeje Eventos Extremos" in Portuguese) was developed and applied in Campina Grande, from May to June of 2019. The project aimed to promote engagement opportunities, where different stakeholders could contribute to the water management of the city. The "Planejeee" had three main goals: (i) to determine the weaknesses and strengths for flood management; (ii) to understand the current context of the engagement between stakeholders in the water management; and (iii) to collect suggestions of strategies/measures for the reduction of flooding and water shortage cases in the city.

The approach was divided into three main phases: preparation, participation and analysis. Each step aimed to promote different engagement strategies with stakeholders (Figure 3). Extensive research was conducted to review other citizen science studies, and GIS-MCDA approaches in similar fields, the planning legislation and city council documents to set a baseline context for evaluation in the questionnaires. Ethical clearance was obtained through the host university (University of Exeter). A pilot questionnaire was applied online from March to May of 2019, with 48 participants.

Engagement and collaboration with stakeholders → Challenges and solutions for water management → Impacts in decision-making and proposal of solutions

Fig. 3. Methodological steps of the participatory approach (dashed lines shows the subjective phases and solid lines indicates the objective phases of the PLANEJEEE Project)

The residents were selected with a basis in the flooding cases dataset, provided by the Civil Defence, and by suggestions from the residents themselves with a total of 172 households interviewed (Figure 2b). Specialists and policymakers were asked to join the workshop and focus groups by invitation, according to their research field (for specialists) or position in the city council (e.g. planning, urban services, engineering, health, education, traffic, mapping, science and technology), water companies (e.g. AESA and CAGEPA) and to the society (e.g. Civil Defence, CONCIDADE, NGO). Here, the expectation was to engage with different sectors in the city council and other fields that support water management. 27 people attended the workshop and focused groups with 22 survey answers (total participants, n = 199).

In the focus groups, with support of GIS (Geographic Information System), we provided a “baseline” material to each group, with maps that indicated vulnerabilities and exposure of the city. For example, we provided maps the most recent census data [11] for structural vulnerabilities (i.e. garbage in the street, streets without drainage system), physical characteristics (i.e. elevation, slope, distance to rivers, lakes) and social characteristics (i.e. population, number of elders, children) [11]. Participants were directed to use this information as input to analyse the challenges and solutions for water management. At the end of the workshop, each group provided a summary of findings to the other groups, and all the participants were asked to contribute. Stakeholders in the focus groups discussed, identified and agreed on implementable strategies for four flooding cases in the city. All the contributions were recorded by the PLANEJEEE team.

These opportunities and questionnaire answers aimed to discuss current challenges and strategies to mitigate water-related hazards in the city. The participatory approach was possible through a collaboration of 10 students (postgraduates and undergraduates of Civil Engineering) of the Federal University of Campina Grande (UFCG). All the methodological steps can be seen in Figure 3.

4. RESULTS AND DISCUSSION

Although the participatory approach provided a range of data in different fields, this paper will only focus on the results obtained with the residents’ participation and focus groups with policymakers and specialists in the research. The analysis will present how the residents differently see the water scarcity and flooding hazards, based on their own experiences and perceptions, and how the policymakers and specialists see the challenges and solutions for four study cases spread in the city.

4.1 Residents participation:

The questionnaire was built in order to cover five main areas: (i) social characteristics, (ii) personal experiences, (iii) management, (iv) protection measures and (v) feedback. Since the city faces two water-related hazards, water shortage and flooding, the same questions were applied to each hazard, summing 60 questions. This paper will cover some of the questions and their implications in water management. The first area covered general characteristics that would be used to analyse data from both hazards. For example, personal characteristics (e.g. gender, education, monthly income, employment, etc) and social aspects related to living conditions (e.g. property type, number of people and period living in the households). Figures 4a, 4b and 4c show that from the total, 80% of the citizens receive less than 2 wages monthly, 75.3% own the property, and 69.8% live in the same place for more than ten years. These questions were important to further evaluate the previous experiences with the hazards and the application of self-protective measures at a household level.

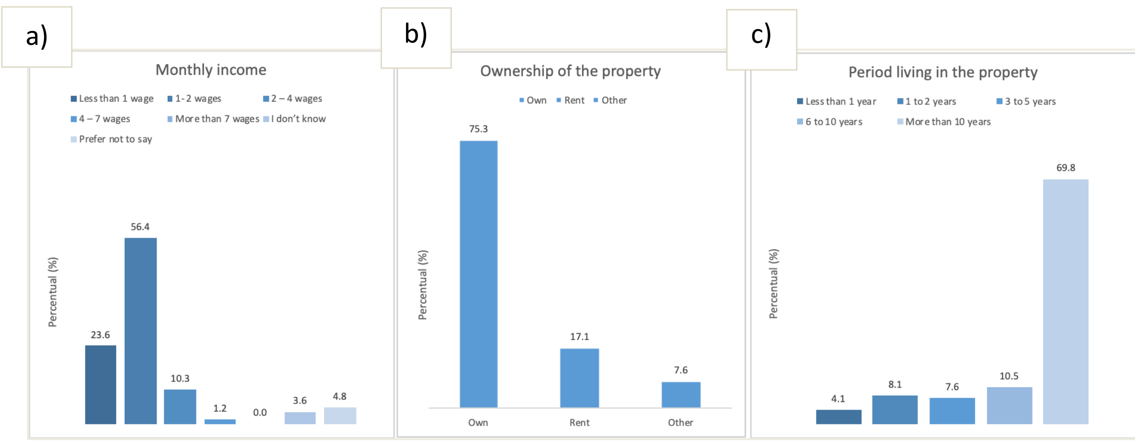

Fig. 4. General characteristics questions: a) monthly income; b) ownership of the

property and c) period living in the property.

The locations for questionnaire application were mainly based on data shared by the Civil Defence that provides locations with flooding complaints from 2004 and 2011. Even though the selection of areas was flooding based, 95.9% of the residents confirmed to have had experienced water shortage events before (Figure 5c). 94.8% confirmed flooding experiences, in which 83.4% classified their severity as moderate-greatly (Figures 5a and 5b). For the severity of water shortage, 58.4% ranked in the moderate-greatly interval (4 and 5 Likert-scale). This confirms the water shortage event occur spread in the city and not only localised. Even though the water rationing splits the city into only two operational zones, the severity of the water shortage periods in mixed (Figure 5d), where 58.4% considers the severity as moderate-greatly (4 and 5 Likert-scale). This can also indicate people have adaptation measures (e.g. water butts or tanks) to reduce the impact of water rationing periods.

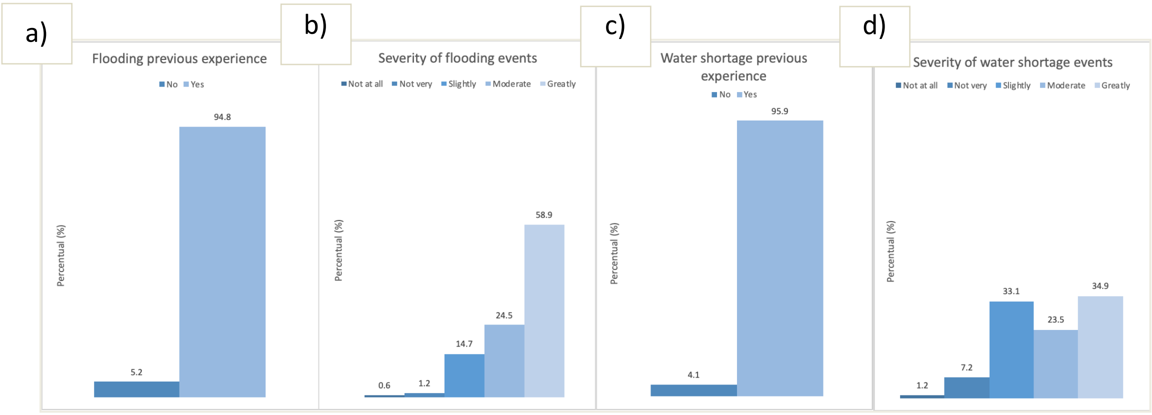

Fig. 5. Previous experiences; a) flooding; b) flooding severity; c) water shortage and d) water shortage severity.

When asked about the risk communication and management, 49.6% usually inform themselves about the extreme events by television and 25.8% by internet, social media and websites (Figure 6a). This question was particularly interesting because only 0.4% affirmed public authorities communicate when a water shortage and flooding is going to occur. Although the flooding can be hard to predict [13], this was questioned to understand the overall context of risk communication to residents. To evaluate this issue in-depth, and to each water-related hazard, they were asked directly on what scale (from 1 to 5) does the public authorities provide a warning before the extreme event occurrence. Figure 6b show approximately 72% affirmed to do not receive flooding warnings from public authorities. As expected, the distribution of answers is different to each hazard, which can indicate the water shortage risk communication from public authorities is more efficient than with flooding (Figure 6b).

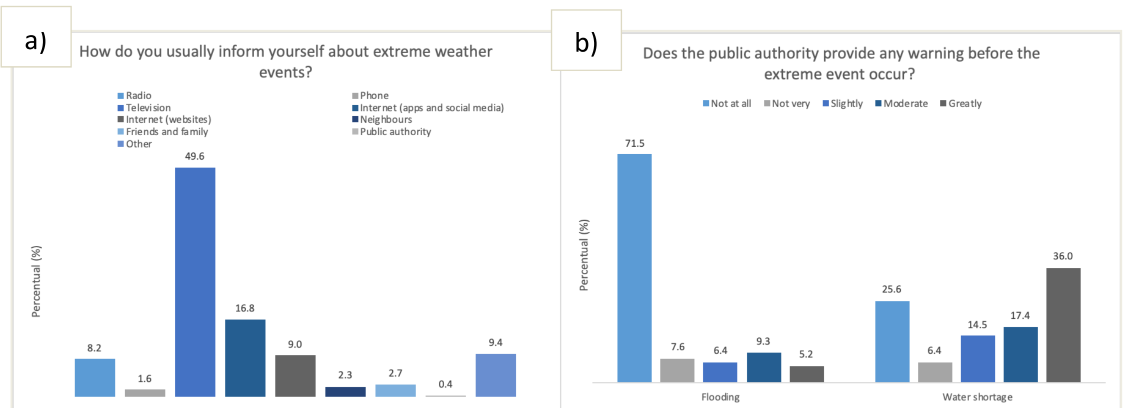

Fig. 6. Risk communication: a) sources; b) scale of public authority risk communication.

One of the goals with the participatory approach was also to investigate what are the motivators to apply self-protective measures at home. The residents could answer each option with the 1 to 5 Likert-scale and, further, in the questionnaire, they could suggest other options. This question aimed to evaluate how the residents see different reasons to apply measures in their household. 12.8% of residents affirmed they would not implement measures even if it were a mandatory requirement. This value reduces to 1.2% and 1.7% if they received monetary incentives or if a severe hazard affected them in the future. This can represent the level of trust they have in authorities. On the contrary, 90.2% affirmed they would apply measures if they had more information about how to do it and 94.8% if they knew it was going to help in the mitigation.

Figures 7a and 7b show what measures the residents are already applying for flooding and water shortage reduction. For flooding, measures such as raising the level of electrical fixtures, storing valuable in upper floors (or higher in the walls) and flood barriers were more common in our sample. Interestingly, these measures are known as possible to be applied with less money. The same behaviour is seen for water shortage. The measures with more acceptance are 90.1% that affirms to wash dishes with less water and 87.9% that take shorter showers. 79.7% confirms to store water in butts, only 7.6% have a cistern, and 1.2% have wells.

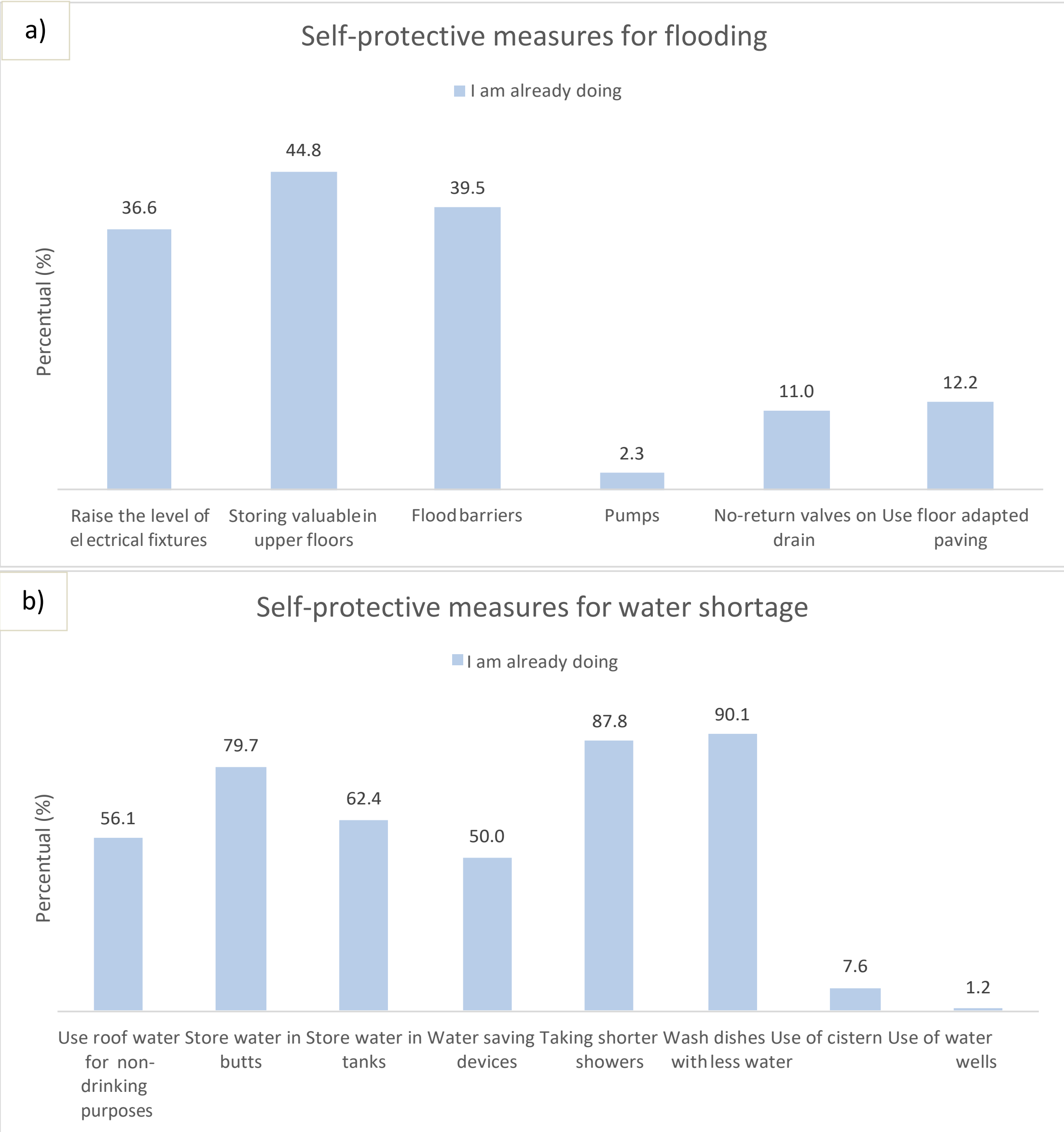

Fig. 7. a) Measures for flooding mitigation; b) Measures for water shortage mitigation.

4.2 Policymakers and specialists' participation:

This phase of the participatory approach aimed to understand current challenges and propose solutions for water management in Campina Grande. The 27 stakeholders were divided into four focus groups, where all of them could discuss specific issues of the area and propose solutions according to the current situation. The division of stakeholders aimed to generate a multidisciplinary group where different sectors of management and specialists could contribute to the problem. Each group had one leader, and guidelines were provided to each with indicators to vulnerability and exposure of residents. For example, data from census tracks were mapped with ArcGIS Pro (ESRI) showing the percentage of households without a drainage system, garbage in the street, monthly income, number of elders, households with wells, etc. This material was provided to guide the discussion in a local-scale perspective.

The engagement with stakeholders of different areas, ensuring a multidisciplinary group, helped to identify enablers and barriers for the water management in the city. The "co-production" of knowledge, with residents, policymakers, and experts, facilitated the problem structuring and interpretation of results. Although public participation is highly recommended, it faces many barriers to effective application in developing countries. Table 1 shows some of the findings obtained with the participatory approach. Each challenge and solution were divided into scales, from location, residents, legislation, management to data.

Table 1. Synthesis table with the main challenges and solutions of water management in Campina Grande – PB

Multiple scales	Challenges	Solutions
Location	Buildings in risk areas[a,b,c] Illegal properties in the flood risk areas[c] Buildings near to channels[c] Low income of residents[a,b,c]	Relocate people from risk areas[c] Create parks in flood risk areas to avoid urbanisation in the areas[c] Develop strategies regarding the socio context[c]
Maintenance	Lack of inspection by authorities[c] Increase of urbanisation[a,b] Problems with design and maintenance of drainage network[a,b,c]	Clearer maintenance and adoption arrangements [a,]
Government	Lack of interest of government[b]	Increase perception at developer, governance and community level[a,b,c]
Legislation implementation	Apply legislation[a,c] Uncertainty of legislation application[c]	Comply of legislation[a,b,c] Engagement with stakeholders[c]
Legislation improvement	Lack of monetary incentives[c] Lack of space in legislation[b] of funds/budget[b]	Development of mandatory standards [b,] Strengthen the Master Plan[c] Lack Ensure a participatory planning[c] Proposal of mitigation measures in context with other hazards[a,b,c]
Risk perception and coping capacity of citizens	Lack of knowledge and awareness of the population[a,b,c] Low flexibility of population[a,c] The social link between residents and the place[a,c]	Communication with residents[a,b,c] Raise perception and coping capacity [a,b,] Promote educational actions with residents[c]
Engagement and communication of stakeholders	Lack of appropriate risk communication[a,c] Lack of public participation[c] Lack of communication between stakeholders[b,c]	Promote a "shared responsibility" campaign in the city council sectors and residents[c] Promote "capacity-building" for stakeholders [c]

[a]= survey for group A (citizens), [b] = survey for group B (policymakers and specialists), [c] = workshop and focus groups, Promote collaboration between stakeholdersc

5. CONCLUSION

We developed and applied a socio-environmental approach, in which each variable of disaster risk was tackled with social and environmental sciences. The PLANEJEEE Project integrated stakeholders of different areas and positions to define the current context of the city related to water management. Our results expressed different behaviours and perceptions of residents regarding each water-related hazard, which can indicate that different approaches should be considered to the management of each extreme event.

The participation of policymakers and specialists enabled the identification of challenges and solutions for water management according to real cases of Campina Grande-Brazil. This shows the importance of developing approaches according to the current context, including vulnerability, exposure and hazard indicators. The integration of local knowledge with additional scientific and technical knowledge can improve disaster risk reduction and adaptation. We believe this strategy can provide more confidence to select and propose mitigation measures for the city.

Next steps of this research will evaluate these and other results from the Planejeee Project for the definition of risk perception and coping capacity, their spatial correlation and influences in positioning mitigation strategies on a local scale. For this, a methodology is being developed, and key factors are being statistically analysed to each index and variables.

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Exploring Smart Rainwater Management Systems in a Small Island Economy

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ABSTRACT

Aims: To investigate the feasibility and benefits of installing domestic-scale smart rainwater management systems (RMS) in an island setting.

Study Design: Modelling exercise for installations at 100 domestic properties on the Isles of Scilly; development and installation of pilot systems.

Methodology: 1) Desk-top modelling of the Isles of Scilly to investigate potential value in terms of annual potable water savings.
2) Install, operate, monitor and control RMS to maximise rainwater re-use, minimise potable water use and reduce peak demands on the potable supply system by proactively topping up the systems.

Results: 1) Demand profiles can be extracted from monitored data and used to iteratively improve performance of the RMS
2) The automated control system was able to shift mains top up demand to periods when the water network experienced low demand, even when rainfall was unavailable to feed WCs.
3) Logistical challenges of installation in an island setting have been explored.

Conclusion: Based on preliminary data, cost-benefit analyses indicate that such an approach could be economically advantageous when considered against traditional resource management solutions. Future water supply upgrades on the island would likely require more desalination, hence offsetting potable water demand may be attractive as a means to reduce total carbon footprint on the islands. Based on experiences to date, deployment of RMS represents a novel way to manage water demand in this unique island setting.

Keywords: Rainwater management systems; rainwater re-use; smart rainwater harvesting; water efficiency.

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1. INTRODUCTION

The Isles of Scilly are a cluster of islands off the coast of Cornwall. They are a popular tourist destination, with a standing population of c.2,200 rising to approximately 4,000 in the summer months. Water supply on the main island of St Mary's comprises a legacy network of boreholes, desalination and an aged water supply network. South West Water (SWW) took on the water and wastewater network on the Isles of Scilly on 1/4/2020. As part of this process, SWW are exploring innovative demand management solutions at a series of case study catchments, to help secure sustainable water resources into the future. As such, this pilot project was initiated to explore the costs, benefits and practicalities of retrofitting Rainwater Management Systems (RMS) at domestic properties [1]. For our purposes, the term RMS encompasses a broad class of plot-scale rainwater harvesting solutions which can be designed or configured to achieve specific water demand and stormwater control benefits

Prior to 1/4/2020, water resources on the island were operated by the Isles of Scilly Council and comprise (on St Mary's where most people live) 4 No. groundwater borehole sources, 7 No. cliff-side saline boreholes and, during the summer months, a seawater intake feeding the desalination plant to support peak demands. The islands' base geology is granite bedrock, which along with space, cost and topographical constraints limits the scope for developing further groundwater sources.

SWW is currently exploring best value options to ensure the long-term resilience of the water supply to protect the resident population and the islands' key tourism industry. With significant experience in domestic and plot-scale rainwater solutions [2], SDS Ltd was commissioned by SWW to model, install, operate and monitor ten smart RMS such that the potential benefit of this technology can be evaluated and other practical considerations, such as property owner engagement and logistics of installing such solutions in an island setting can be understood.

2. METHODOLOGY

The methodology formulated to investigate the project objectives included: 1) Analysing potential solutions by undertaking desktop modelling; 2) Installation of bespoke RMS units at identified locations; 3) Monitoring and analysing the collected data from these systems. These steps are described in the following sections.

2.1 Modelling

Many approaches have been developed to enable rainwater harvesting to be evaluated by the global academic community [3]. Building on this work, a mass balance modelling tool was developed that facilitates iterative design evaluation for RMS using the Yield-After-Spill approach [4]. The model operates using a mass balance wherein rainwater is stored, spilled or used at each time step (here daily). After reviewing rainfall statistics across 20 years of daily data, the output from a typical year (here year 2013) for an RMS based on an 800 Litre tank installed in St Mary's is illustrated in Figure 1. The model was run for the same parameters as the property which received the installation considered in the results section of this study.

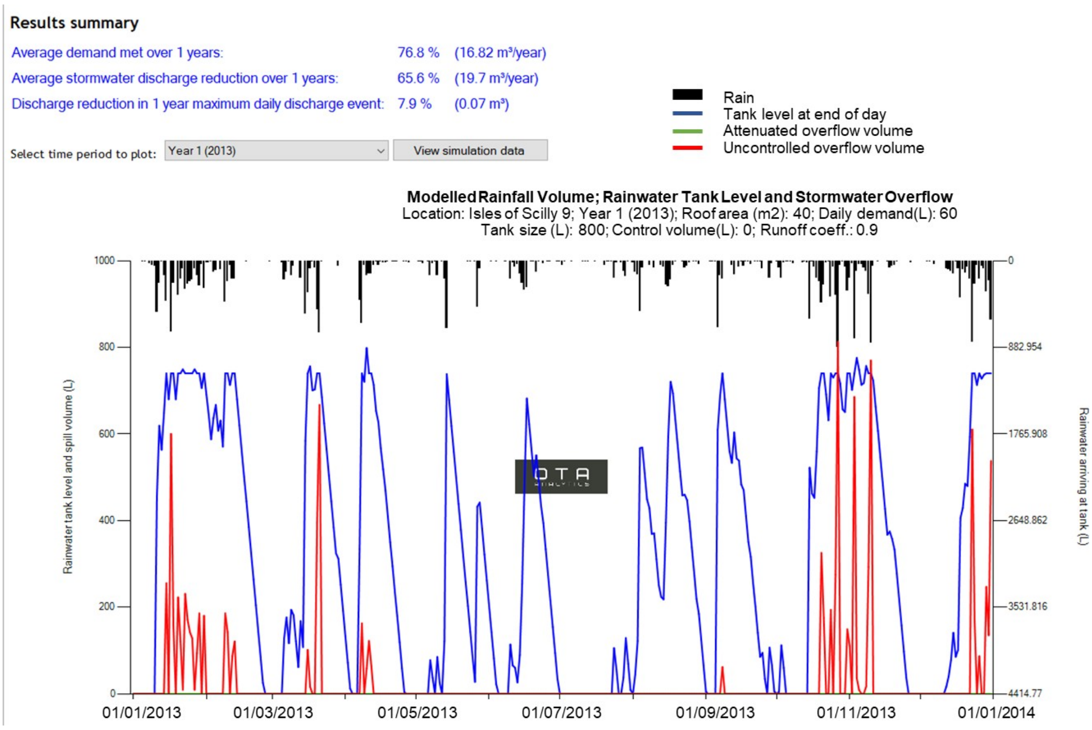

Figure. 1. Modelled rainwater tank level (blue), uncontrolled discharges (red) and results summary (top of figure) for an 800 Litre rainwater management system configured for traditional rainwater harvesting, feeding a single toilet (at a rate of 60 Litres day^{-1}) from a 40 m^2 roof area in Isles of Scilly, UK.

The modelling tool was designed to enable water resource planners to model the performance of a range of RMS driven by different rainfall timeseries. The modelling stage of this project involved the development and assessment of models for a range of RMS configurations, principally focussed on plot-scale retrofittable solutions. Project constraints (including budget, logistics and potential partners amongst others) limited the size of storage tank the RMS configurations could be based on to under 1000 Litres.

The modelling exercise aimed to explore how the implementation of such systems could benefit the water resource position on the Isles of Scilly. The exercise evaluated the benefits of three different operational philosophies over a 20-year period (1996-2015). These operational philosophies included: 1) Traditional rainwater harvesting whereby rainwater is collected from the properties roof area and stored in the tank. This water can be reused in the connected toilet or in the garden. Once the tank is full, any additional rainwater will spill to the drainage system; 2) Passive control RMS whereby the system operates as for traditional rainwater harvesting but is also fitted with a release mechanism causing the tank to slowly drain to a given depth over time; 3) Active control, whereby the system operates as for traditional rainwater harvesting but is also fitted with a dynamic top up and release mechanism which can be configured to optimise the depth of water in the tank towards various goals, primarily the minimisation of day time water demands.

The rainfall data used in the modelling exercise consisted of daily total accumulations derived from the United Kingdom Meteorological Office's Hadley Centre regional rainfall observation datasets for South West England & Wales [5]. As part of the modelling effort, years which could be considered wet, dry and typical were identified to ensure RMS configurations were robust across a range of conditions.

A representative sample of 100 properties from St Mary's, Isles of Scilly was identified using geospatial data. This same data provided approximate roof areas for the selected properties. A range of supplementary data sources including census data and the British Standard for Rainwater Harvesting (BS: 8515 2009) were then used to model property size, occupancy rates and demand distributions. This information was combined with the RMS configuration discussed previously to generate a suite of scenarios which were fed into the software tool for analysis.

2.2 Installation

A series of 600-1000 Litre above ground RMS were installed between March and May 2019 at two pilot locations on St Mary's, Isles of Scilly as well as seven locations in Exeter. The Exeter installations were used as surrogates to expand the data gathered by the trial while simplifying the practical and logistical considerations inherent in running a trial solely on the Isles of Scilly. Further, an existing 2500 Litre below ground tank was also upgraded and monitored as part of the trial, to test practicalities associated with retrofitting the monitoring and control systems at existing assets.

Each RMS was equipped with a monitoring and control platform. These platforms were configured to allow rainwater to be dynamically released from the rain tanks by remote command in order to manage the available storage. They were also able to supplement the rainwater collected by the tank with potable water via an air-gapped backup regulated by a controllable valve. This ensured that the appliances (i.e. toilets) connected to the systems could function even in prolonged dry periods. Using a submersible pump, each system was able to supply water to a single toilet within each property. The 2500 Litre system also supplied a domestic washing machine. In addition to being dynamically operable, the actuation points in the system included set-point based control routines which ensured overflow and potable water backup functions acted to regulate the state of the system at all times. Each RMS was configured with bespoke set-points which could be updated remotely as needed. Due to this novel configuration, the systems could be managed predictively using weather and demand forecasts to create additional storage in advance of rainfall events and smooth peak demand by topping up the tank at strategic times. Each system also included a suite of sensors.

2.3 Monitoring and Control

The monitoring and control systems for each RMS were formally commissioned during April and May 2019. The systems operated at 24 Volts DC supplied via the properties mains electricity and an appropriate AC-DC converter. The systems used a 3G/GSM communications module in order to communicate with the real-time monitoring and control system. Each system included a standard suite of sensors and actuators (Fig. 2) which included: a pressure transducer to monitor the depth of water in the tank (the key control variable); temperature sensors monitoring water and ambient air temperature as well as the temperature inside the monitoring and control system; flow sensors monitoring the supply to the house and the potable water supply to the tank; and two valves to regulate the release and backup functions. The systems were configured to record data from the sensors at a timestep of 1 minute. A typical installation of an RMS with monitoring and control platform is illustrated in Figure 3.

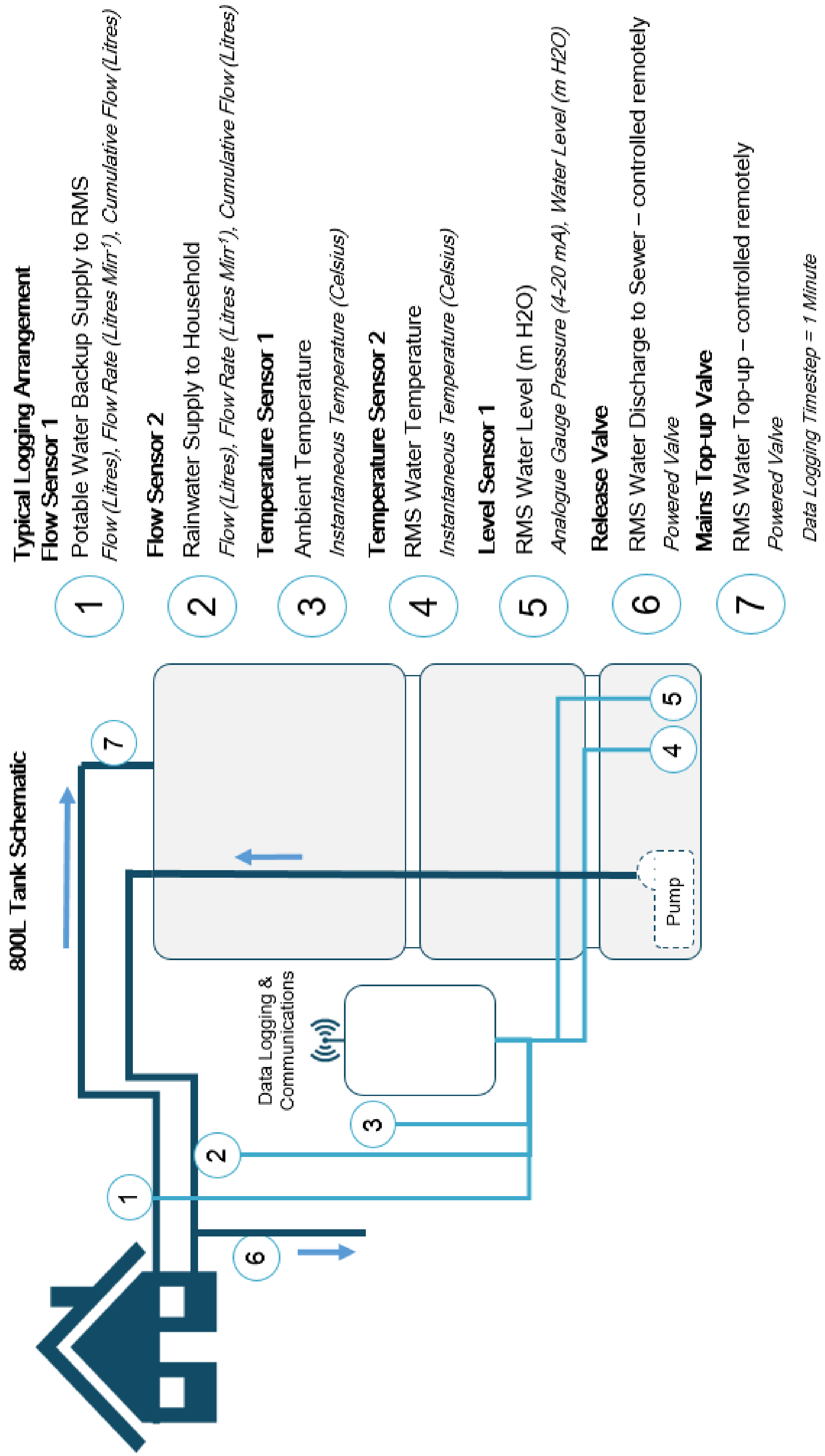

Figure 2. Monitoring and control arrangement for a typical smart rainwater management system deployed in this project

Figure 3. A smart rainwater management system retrofitted at a property on St Mary's, Isles of Scilly

3. RESULTS AND DISCUSSION

Data collection and evaluation is ongoing and will be complete for all ten properties in late summer 2020. The initial phase of the project focused on exploring the practical installation elements of signing up householders and executing retrofits. This stage was successful and initial feedback from the recipient community is that further installations would be welcomed.

3.1 Modelled Benefits of Installation

For the purpose of comparison Figure 1 illustrates the modelled performance of a RMS installed at Participant 9 in St Mary's. This model output suggests that 16,820 Litres (77%) of annual toilet demand would have been satisfied by the 800 L RMS for a typical year (2013). Similar analyses were completed for the 100 properties selected in the desktop trial over the period 1996-2015 to establish an overall water demand saving of 20,017 Litres/annum/house.

Further work is now necessary to explore the potential costs and benefits of "at scale" retrofits. It is estimated that across St Mary's 300 domestic properties (commercial premises have not been considered as part of this study) may be suitable to receive installations. The CAPEX for such a scheme can be investigated against the alternative water resource options as further plans are developed.

3.2 Installation, Operation and Insight from Real-time Data Feeds

Remote monitoring for the project has been successfully in both Exeter and St Mary's using existing mobile phone infrastructure. Control philosophies have been successfully implemented remotely and evaluation of the data will be undertaken for the full 12-month trials as illustrated in Figure 4. Preliminary data reviewed for two households shows a consistent water demand pattern for the WC usage. Further investigation is necessary to evaluate these demands, but the linear drain down of the tanks between storms implies that a regular daily demand can be assumed when modelling such systems. A dashboard was set up to enable the project team to visualise outputs from the monitoring and control systems. An initial review of data from two Exeter-based participants is illustrated in Figures 4 and 5.

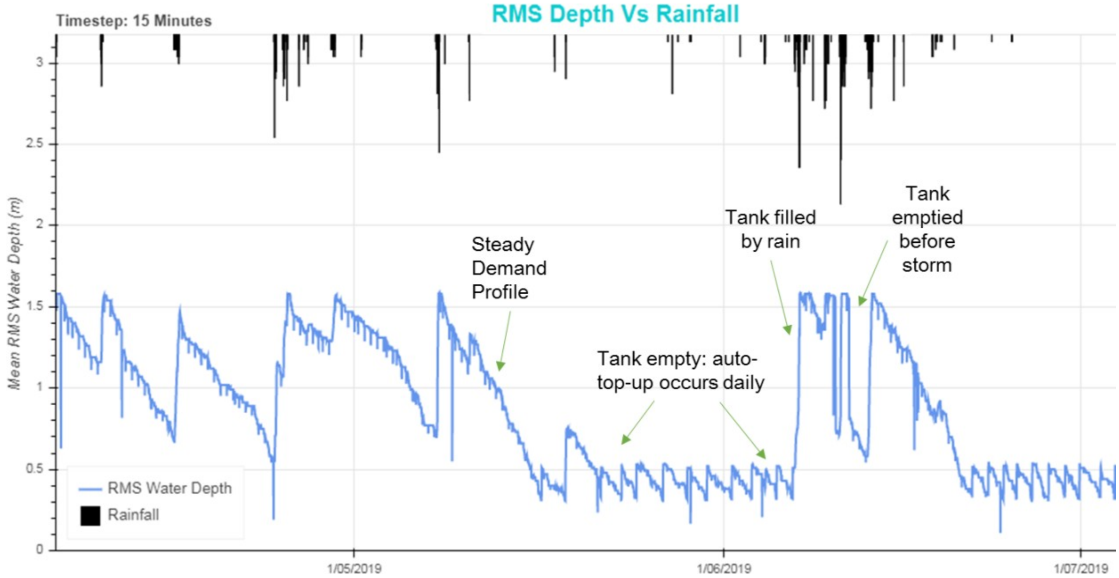

Figure 4. Dashboard output for rainwater tank performance of smart rainwater management system retrofitted at participant 4 in Exeter for three months in summer 2019

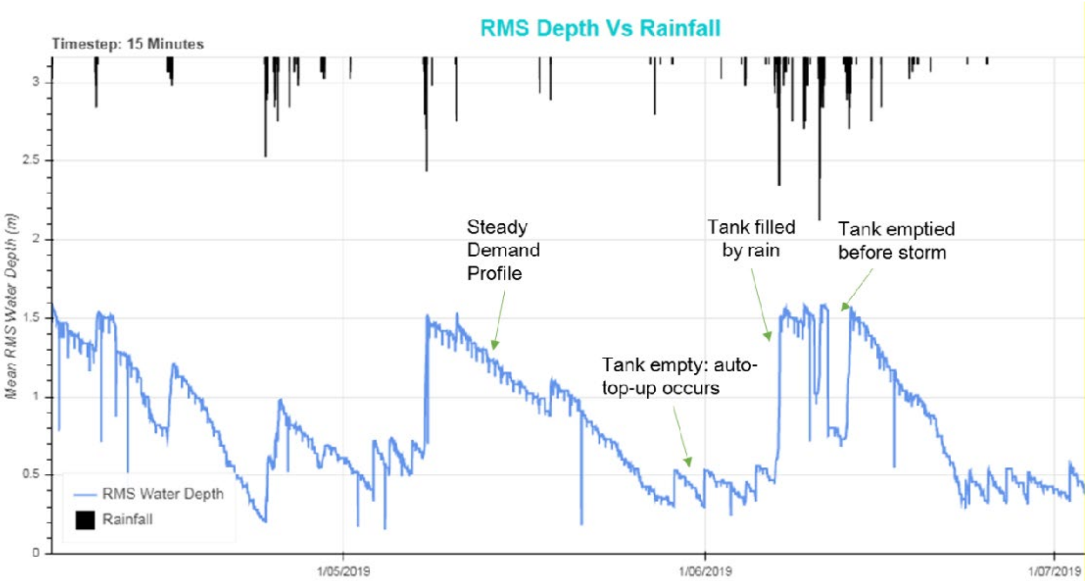

Figure 5. Dashboard output for rainwater tank performance of smart rainwater management system retrofitted at participant 5 in Exeter for three months in summer 2019

The data shows that the top-up and release mechanisms have been operating as intended to maintain steady rainwater availability whilst releasing rainwater from the tanks prior to storms. Further detailed analyses are warranted when the annual data set has been collated.

3.3 Preliminary data from Isles of Scilly

With the study ongoing, preliminary data has been analysed for one of the properties retrofitted in St Marys. Table 1 below illustrates key performance metrics the system. As is evident from

Figure 6, the system was initially operated with target water level of >0.4m and was permitted to draw mains water at any time. The night-time top up of mains water was activated remotely on 15/07/2019 and the minimum water level target raised to 0.85m. After this date, the functional storage volume for rainwater was reduced to approximately 400 Litres. However, the increase in target water level also increased the ability of the system to only draw mains water during the night, i.e. when regional water demand was low. The system drew a negligible quantity of mains top up water (35 litres total) during daytime hours in the 261 days since 15/7/2019.

Comparison of the mean daily water demand satisfied by the RMS under the modelled scenario (46 litres / day, Figure 1) against the true performance (33 litres / day, Figure 6) illustrates the importance of accurately defining the functional storage volume and associated control philosophy when evaluating RMS using simulation approaches.

Table 1.Preliminary key performance metrics for smart rainwater management system operated at St Mary's household for ten months from May 2019

Parameter	Data
Location and ID number	IoS9
Data Range	23/05/2019-31/03/2020 (314 days)
Roof Area feeding raintank (m^2)	40
No.of occupants	4
Tank size (m^3)	0.8
Configuration and control philosophy	The potable water backup system is configured such that if the water level in the tank is below 0.6m at 2100 hours it will be topped up to around 0.85m. A secondary, emergency backup is activated whenever the water level drops below 0.25m and tops the tank up to approximately 0.35m (to prevent pump dry- running).
Total water demand for WC (m^3)	18.5
Total mains water introduced (m^3)	7.9
Total demand Met by rainwater (m^3) (% of total demand)	10.6 (57.3%)
Mean daily demand met by Rainwater (m^3)	0.033
Total mains water top-up occurred during daytime (% of total WC demand)	1.56 m^3 (8.4%) of potable water backup occurred between the hours of 0800 and 1800.

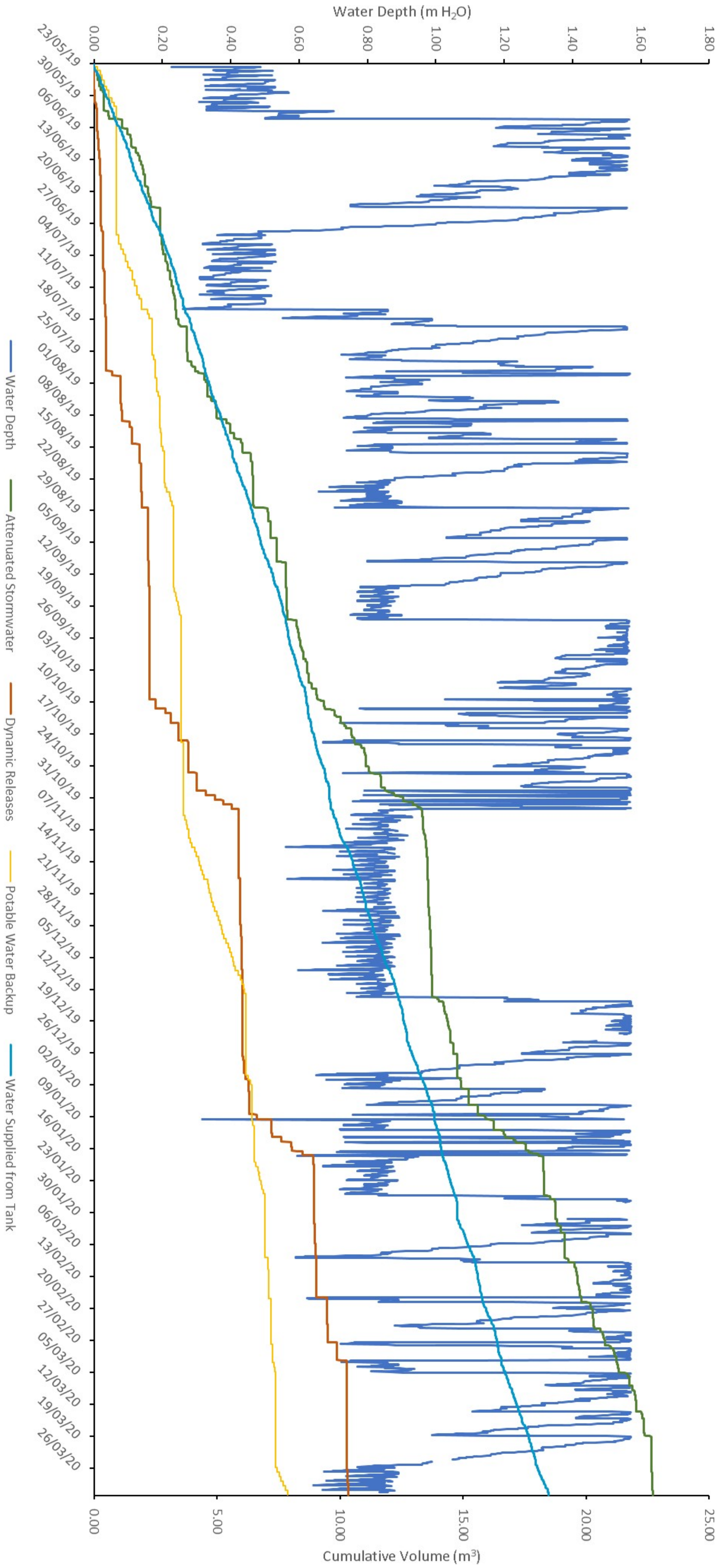

Fig.6. Dashboard output for smart rainwater management system retrofitted at Isles of Scilly Property (May 2019-March 2020)

4. CONCLUSION

Since inception in 2018, the project has successfully modelled the potential benefits of implementing smart RMS as a water demand management strategy in the Isles of Scilly. With nearly 12 months of data now captured, the data collected across these ten systems represents the richest available dataset in terms of resolution and coverage wherein smart control systems have been deployed on UK based RMS. The project has found that the implementation is feasible on a retrofit basis and that the integration of real-time control systems with RMS represents a step forwards in terms of adding value to the operation of RMS. Once completed, the evaluation phase will provide a robust dataset against which alternative operating philosophies can be tested, ultimately, facilitating continued progress in the development of multi-objective RMS deployment both in the UK and further afield.

Based on 10 months data available from a single pilot system described in this study, the retrofittable RMS was found to yield $10.6m^3$ of water. In addition a revised control philosophy successfully enabled the mains water top up to the tank to be achieved during low demand (high pressure) periods, i.e. only overnight. Based on preliminary data:

1) Property-level demand on the RMS show consistent diurnal patterns. Demand profiles can be extracted from monitored data and used to iteratively improve systems performance / project future needs.
2) A control philosophy was successfully implemented to ensure this water demand can be provided by mains water drawn from the mains network overnight during extended periods without rainfall, easing the peak demand on the water network.
3) Future water supply upgrades in the Isles of Scilly would likely require more desalination and hence offsetting potable water demand in this location could be a highly effective means to reduce total carbon footprint of the water usage on the islands.

ACKNOWLEDGEMENTS

The project team are grateful for the support of Professor David Butler at the Centre for Water Systems of the University of Exeter who provided valuable guidance and input throughout the project. The authors are also grateful to Dr Neil Sewell, Director of Technology Systems, SDS Ltd for his comments and review.

COMPETING INTERESTS

The first author commenced the project whilst working as a contractor to South West Water via Over The Air Analytics Ltd. This company is now wholly owned by SDS Ltd. At the time of writing, the first author is not financially linked to the co-authors or project funders. Dissemination has been made possible thanks to the collaborative approach of South West Water and SDS Ltd. It is also noted that SDS Ltd hold a licence to commercialise RMS technologies based on modelling software (illustrated in Figure 1.) that builds on intellectual property initially developed by the first author and the University of Exeter. The project is ongoing and full analyses are intended to be prepared in Autumn 2020.

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Nature connectedness, human behaviours, and blue infrastructure: the water effect to people in historical and contemporary masterplanning.

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ABSTRACT

Most urban designers and planners have produced anthropocentric masterplans since early twentieth century. Today green infrastructure in cities, including blue infrastructure, primarily expresses people's relationship to the environment in terms of resource management. Often the natural world is converted into urban green arrangement or a replica of nature mainly for the economic and cultural benefit of humans. Water and related ecosystems were only part of industry as necessity until late twentieth century. Nowadays, water is valued as a very important element of life. Most experts believe that by offering people the opportunity to participate in running and preserving certain ecosystems could have a very positive impact to human health and wellbeing. Environmental psychology suggests that we can provoke heightened experiences in people's minds by designing dynamic flowing water patterns in urban context. Natural or artificial landscapes, such as green parks should intertwine with the built environment, displaying human creativity and inventiveness. The authors of this paper discuss the importance of water changing culture and behaviours in regenerated green parks in vulnerable urban areas, such as the case study of Arboretum Derby. This particular case study was reviewed by both authors (tutor and PhD student) who shared research with undergraduate students in Urban Design module in this academic year. The student projects reveal the importance of nature connectedness to people seeking happiness and mental balance to counterbalance lockdown hardship, employment loss and social deprivation.

Keywords: Human behaviours; nature connectedness; green and blue infrastructure; mental health and wellbeing; livability versus social deprivation; social and urban regeneration

1. INTRODUCTION

Livability relates to urban design and planning, elements which can influence a city's social mobility and financial prosperity. A livable neighbourhood can be compact, sustainable, diverse, green, healthy, and accessible. Since 2016, one of the authors of this paper and tutor of final year undergraduate students in one of the architectural programmes of the University of Derby working together with her PhD students had the opportunity to take part in live surveys and projects aiming to create platforms of renewal of vulnerable neighbourhoods, such as Normanton Pear Tree and Arboretum suburban areas at Derby. Student projects and tutor's theories and practices have been presented to local communities and in conferences [1]. Derby Homes and Derby City Council invited the tutor and her students to participate in live debates and fora; important biophilic design proposals of masterplanning emerged as the result of meticulous surveying and interaction with the local communities; they were presented to the local communities of Normanton Pear Tree and Arboretum wards as first ideas on 9th May 2018.

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During these activities, by sharing research findings with Derby Homes, we managed to create a first plan on areas and priorities in which Derby City Council and Derby Homes should concentrate in the next few years to improve living standards of the most vulnerable areas in its suburbs. The students managed to create useful maps of the most important nodal points of these areas: the community centres. Normanton Pear Tree and Arboretum wards present a lot of problems, such as increased unemployment and criminality, deterioration in the built environment and infrastructure (transport, green and blue infrastructure). So, students and tutor arranged focus groups and meetings in these centres; we met large groups of representatives of most of the ethnic minority groups who are more than fifty in these two wards. See below a special map prepared by the students, which also shows an itinerary/route of connection/mobility between centres and surrounding areas. The route in red encloses a core area inside the two wards mentioned before. According to the primary resource data collected during the focus group meetings, the students showed several routes and itineraries to residents who showed their preferences by describing how they should like to use the centres by sharing educational, cultural and leisure events, and by spending good quality time together. They felt that they did not need expensive works; they were prepared to put to self-construct, create and enjoy their new environment. Residents of all ages and backgrounds felt cut off from the city centre masterplan and pricey developments there.

Fig. 1. Normanton Peartree Assets Map for Survey. Itinerary chosen by the students as the 'heart of Normanton Peartree'. Source: [Students drawing on excerpt from Digimap, 2018]

So, by discussing further all findings and processes with two PhD students, we proposed to communities and local authorities to establish the distribution of available funds by using potential models of future management and development of public/community assets [2] According to the outcomes and analysis of qualitative materials selected, local authority and communities should cooperate:

- To create a development plan for key community assets in the area.
- To create a framework for an efficient network of organisations.
- To make recommendations on how community cohesion can be improved through the built and natural environment.

- To make recommendations on the future development of open spaces and integrated green and blue infrastructure.
- To advise and participate in bids to secure funding for the future to improve sustainable community assets across the area for the benefit of the people of any age and background.
- And finally, to be able to maintain public health and well-being at the highest possible standards.

However, changes to political agenda after recent elections, many projects related to suburban developments have been on hold, and lately also COVID-19 lockdowns have created more disruption. But we, students and tutor, kept going with work and more research in this academic year, too. In spring 2020, our students in Project Research and Urban Design were introduced to Sustainable Development Goals (SDGs) and 14 Biophilic Patterns [3], [4]. they were taught about Biodiversity and Circular Economy, and above all, they have experienced a sudden lockdown of all activities in their city of studies. The students proposed visions of integration of green and blue infrastructure to help communities to recover, with no more barriers for green and public space. Green parks, such as the historical Arboretum Derby, should expand along pedestrian and cycling routes; they would become the active heart of their surroundings, granting health and wellbeing again. We believe that Derby will become a smart living city, if all its neighbourhoods are committed to achieve and respect their pre-set SDGs and biophilic patterns to apply in their planning and design of both indoors and outdoors

The students were given a brief for Derby Arboretum area new proposal of a masterplan. The Arboretum Derby park is located on the outskirts of Derby City Centre, and it has been a functional park for visitors, pedestrians, dog walkers and cyclists to use since the 1840's, when it was conceived. With vast expanses of grass and buildings located on the site, the park hopes to attract users and promote biodiversity and connectivity with nature. By analysing inspiring precedents and urban and contemporary landscape designs, each student not only developed a proposal for the revamp of the park, but also proposed solutions in plan and urban design to boost pedestrianisation, cycling routes and connectivity. In addition, research into cutting-edge ideas, technology, sustainability, and materials was undertaken to find out how Derby City Council could increase the number of users by attracting Derby City centre and surrounding areas' residents.

2. MATERIAL AND METHODS – METHODOLOGY

2.1 Revitalising Arboretum Derby: blending Biophilic Patterns with Sustainable Development Goals (SDGs)

During the delivery and running of this module in spring 2020, we managed to attend a full day site visit, during which the students had the opportunity to talk to Ruth Richardson, ex-director of Multifaith Centre at Kedleston Road Campus at Derby, who is currently working as a Development Officer at Institute for Youth Work, which *"exists to give you, as a member of Youth and Young Peoples workforce, a voice in the changing times our sector has and will continue to experience …developing our profession to ensure that all young people have access to support, engagement and recreation"* [5] After our presentation in May 2018 to Derby Homes and local communities, Ruth got support from Derby Homes through a small bid for funds to reopen a Café space, owned by the City council inside the Arboretum Derby park. Ruth managed the space of the bar area mainly to create a self-sustained youth cultural and leisure place for Roma community youths in Normanton area. With the help of volunteers from Friends of Arboretum and some works advanced by Derby City Council, Arboretum Derby started its return to what was the intention of the donation to the general public since several decades ago: to be a place where people of Derby and Normanton could enjoy nature, daylight, and breathe clean and fresh air. A couple of centuries ago, when the industrial era took over people's health and wellbeing in a harmful way, green spaces like this were very much appreciated especially by working families at the end of a tiring day or week.

Arboretum Derby was the first designed urban park in Britain, designed by John Claudius Loudon and commissioned by Joseph Strutt. The park was donated to Derby for the benefit of citizens in 1840. John Claudius Loudon also constructed and planted the original gardens; he was inspired by the Boboli gardens of Renaissance Florence and by Baroque master Pietro Tacca (1577–1640) for the fountains, statues and uses of water. Some of the trees are listed and are notable within the British Isles Tree Register and recorded by the Forestry Commission. Arboretum Derby first opened to the public on Thursday 17th September 1840 [6]

The site is located to the south west of the city centre in Derby. The surrounding areas consist of houses and small businesses. Due to the large scale of the site, it means that there is minimal sun blockage from the surrounding buildings. The majority of the site receives high volumes of sun throughout the day, however there is a high level of foliage which will result in a lot of shadowing within the green spaces. The site has many entrances which allows a high level of permeability throughout it; this can be seen as a negative or positive factor in the accessibility to all. In its current state though, the Arboretum park despite being full of greenery is very dull. The park's design is dated and, despite a few upgrades in the past few years, the site lacks a welcoming atmosphere and struggles to highlight the unique features of the space in which make it worth visiting.

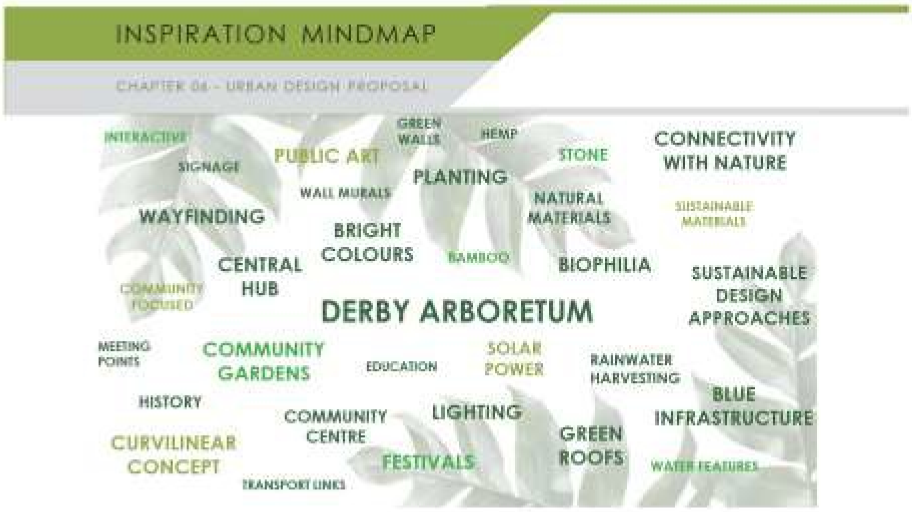

Fig. 2. Inspiration mind map from student work in Urban Design module, 2019-2020

For their projects, the students made their own decision on which Sustainable Development Goals had to focus more for the benefit of the local community. They also had to decide how many Biophilic Patterns and which ones should be appropriate for their proposed urban design and planning solutions.

3. RESULTS AND DISCUSSION – THE PROJECTS

Green and blue urban design can be categorised through multiple biophilic design principles. By utilising live planting and water, which can be otherwise known as green and blue infrastructure [7]. The implementation of blue infrastructure into an urban environment can be as important as the implementation of green infrastructure. Something as simple as a water fountain or an ecological pond can be classed as blue infrastructure. By introducing water into urban environments, it promotes recreational activity as well as relaxation; both of these aspects of human life have a positive impact on human health and wellbeing. This is an important factor considered in all projects in alignment with the regeneration of Derby City, too. Water is an important factor within urban design; it promotes healing purposes; this is due to the human hereditary comfort found in the presence of water [8].

The impact of blue infrastructure was considered in all projects. By incorporating blue infrastructure into urban spaces, it contributes to the enjoyment of living near these kinds of places. This impact is very much comparable to the effect that the green infrastructure has on humans. Within a study conducted by some authors, several photographs of natural environments were used that should elicit different responses within a human mental health [9]. These can either be negative or positive responses. Although aquatic environments are normally recognisable by water, for example, seas and lakes, a secondary aspect of water scenes can be recognised by fountains or streams. This investigation through photographs outlined human preference for water, and specifically for the quantity of water represented.

Blue infrastructure can influence humans by direct exposure to water contributing to mental health. Water within environments encourages healthy living by creating opportunities to exercise, as well as increasing the aesthetic aspects of the space by water contributing to mental health. By utilising the existing blue infrastructure of the site, students promoted human health and wellbeing; the intention is to educate the community on the ecosystems and how water management could sustain beauty in parks, such as Arboretum. Waters within urban areas are an opportunity for leisure activities such as fishing, boating, etc., but also can provide the environment with a more pleasing experience to humans, whether it be for a view or a route to walk round. Subsequently, very often the presence of water is combined with arts and their healing power.

Fig. 3. Expanding blue infrastructure in Arboretum main avenues, student projects in Urban Design, 2019-2020.

Art can be used to create environments or enhance environments to promote healing benefits. Art reveals the beauty in the world and alters the human brain's chemistry and spiritual awareness. Art can sometimes be key to healing and personal growth when one feels they can connect with a piece of artwork. Through art, people can connect with other people and create community. As well as this art can be a useful way of expressing emotions that are too difficult for people to put into words. If an artist is able to portray these emotions then the people viewing their artwork may feel like they belong more, therefore giving the art a more in depth meaning. The perception of art, especially those of an abstract nature can encourage humans to develop their own story of the work, which can have benefits on their perception of what they could be dealing with [10]. Art can change our perception on how we experience the world:

> There is an increasing amount of scientific evidence that proves art enhances brain function. It has an impact on brain wave patterns and emotions, the nervous system, and can raise serotonin levels. Art can change a person's outlook and the way they experience the world [11]

In 2018, Richardson suggested that art can capture the beauty within nature and elicit the feeling of nature connectedness within humans, fundamentally causing a positive influence. In fact, an increase in human nature connectedness through art can have interpersonal benefits for everyone [12].

In relation to the discussion above, we wish to refer to a specific instance which happens in the Arboretum park. Joseph Strutt had commissioned a copy of the famous *Il Porcellino* (Italian 'piglet'); that is the local Florentine nickname for the bronze fountain of a boar. The fountain figuring a boar was sculpted and cast by Baroque master Pietro Tacca shortly by 1634, following a marble Italian copy of a Hellenistic marble original at that time in the Grand Ducal collections and today on display in the classical section of the Uffizi Museum [13]. Tacca's bronze, which has eclipsed the Roman marble that served as model, was originally intended for the Boboli Garden, then moved to the Mercato Nuovo in Florence, Italy; the fountain was placed originally facing east. But to gain more space for market traffic, it was later moved to the side facing south, where it still stands as one of the most popular features for tourists. The present statue is a modern copy, cast in 1998 though as the original was moved to a museum in Florence.

Fig. 4. Il Porcellino at Arboretum, © photograph by students in Urban Design, 2019-2020

Visitors to *Il Porcellino* put a coin into the boar's jaws, with the intent to let it fall through the underlying grating for good luck, and they rub the boar's nose to ensure a return to Florence, a tradition that has kept that nose in a state of polished sheen either to the original and the copy today. There is a strange appreciation of the *Porcellino* copy/piece of art at Arboretum though. In the case of Arboretum's *Il Porcellino* though, which stands on a pedestal nowadays, and without water around it, people from several ethnic groups at Normanton use to touch some other exposed parts of the body of this boar, as a good omen to the fertility of themselves and their families' increase. Nevertheless, this statue by Tacca has been related to health in another case; another replica sits outside Sydney Hospital in Australia. Pietro Tacca has contributed to several statues and fountains in Florence and Livorno, such as the fountain in Piazza della SS. Annunziata in Florence, artwork showing grotesque masks and shellwork textures.

4. CONCLUSION

In conclusion, all students managed to prepare very interesting solutions for the park and the area. We are now planning to celebrate 180 years of Derby Arboretum by creating an exhibition on site later in autumn 2020. The aim is to get feedback mainly from the local communities and invite Derby Parks and derby City Council to a public presentation. We value the public opinion first, as tutor and students are planning to start discussions about self-build processes in urban space by getting local community youths participating actively to learn new skills and start new jobs which are desperately needed in the whole are of Normanton.

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The authors wish to thank all students/participants in this project for Arboretum from Module Project Research and Urban Design, BA (Hons) Interior Architecture and Venue Design, graduating class 2020. They also wish to thank especially Ruth Richardson for organising such an amazing site visit in early March, few days before the latest lockdown. We also express our gratitude to the local communities for their help in research findings/collection of data until now. Special thanks to our colleague Briony Norton who interacted with all students in a special workshop on Biodiversity in urban spaces.

COMPETING INTERESTS

We declare that the work for this project has been a research and pedagogical exercise within our learning and teaching time as staff and students. No funds received from any external sources.

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#2. Innovation & integration for resilience in resource, product & policy practice

Attacking the right-hand tail

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1. WHAT IS THE RIGHT-HAND TAIL?

When we talk about the right-hand tail, we refer to a skewed distribution. The more we understand about water consumption, the more we realise it is far from normal, in a statistical sense, and that there is no such thing as a normal property. Household consumption is regularly reported as a single average figure, but this masks a skewed distribution. Artesia's modelling has shown daily personal water use has a modal value much less than the mean value of around 140 litres per head per day that is widely quoted. This means that most properties are already using a relatively low volume. A few extreme properties are dragging up the overall mean.

2. HOW TO CAPTURE THE RIGHT-HAND TAIL

(Generally, we expect PHC to be between zero and around 2,000 l/day. However, the better the data, the more we can understand about the data, then this leads to better confidence in the data. We can now distinguish what would normally have been classed as outliers into erroneous and extreme data. By better we mean a more granular timeseries, less erroneous values, and greater number of properties. To capture and understand the right-hand tail we assess individually measured properties. Often, consumption is calculated from the differential between two meter reads over a 6-month period and is therefore averaged over that period. Manual meter reading causes additional uncertainty and therefore a cap is often set to avoid erroneous data being captured within the estimate.

High resolution, smart meter and more frequent AMR consumption data is far superior for capturing the right-hand tail. Removing the reliance on human transcription improves the accuracy of the data, and therefore remove the need for removing erroneous outliers. Increasing the frequency allows us to better validate those high readings. Over the past few years, we have been working with several water companies to embed these new data sources into their reporting and have learnt a huge amount along the way. South West Water (SWW) installed Ashridge loggers, which are high resolution loggers across their measured and unmeasured Individual Household Monitor (IHM). This high-resolution data meant that we were able to investigate these extreme users and start to investigate continuous flows in terms of wastage within the home (e.g. from a leaky toilet) and losses on the supply pipe between the

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meter and the property (known as Customer Supply Pipe Losses or CSPL). Properties with >20,000 l/day of consumption genuinely do exist.

What SWW gained was confidence in the consumption data they collected, but it raises important questions about whether the IHM is representative of the population. How many properties would we expect to have this extreme level of consumption? They do certainly exist but considering the extreme impact of properties like this on the average PCC then it is important to understand their prevalence.

Working with smart meter data from over 450,000 Thames Water households allowed us to put these theories into practice. Where SWW triumphed in timeseries granularity to give us confidence in these high consumptions, TW truly triumphed in property numbers. What we found was the same, most properties have modest consumptions, some have high consumption and a few properties have extremely high consumption. We have now been able to prove what “normal” household consumption looks like, and that it is extremely variable. This inevitably means that there is a long tail of household customers who have a much higher consumption rate and are therefore a potential target for 'quick-wins' through household audits, wastage repairs and behaviour change.

3. WHAT CAUSES THE RIGHT-HAND TAIL

Extreme use from people and properties can be caused by behaviour and water using devices. Some of household consumption is predictable and modellable, but as we said previously it is highly variable. The water industry has become pretty good at reporting and forecasting company level or zonal level consumption. Up until now, the major driver for understanding household consumption is to ensure that the water balance is accurate, and to ensure that the supply demand balance is maintained throughout the mandatory forecast period, so that we don’t run out of water.

Recently the game has changed when financial ODIs from Ofwat being set for PCC as well as leakage. There is now a regulatory target to reduce consumption, and therefore a need to better understand consumption. How does a water company reduce high consumption without understanding it? Up until now there has been limited drive to understand property level consumption, and not a huge amount of data to be able to fully understand the concept.

We expect certain properties to have higher consumption than others. Higher occupancy, more water using devices, bigger houses, and bigger garden. Broadly this is true, and this can be modelled and predicted, and in a general sense the differences between properties quite well understood. However, this means that we over predict consumption in most properties and underpredict some of the large properties by a significant amount.

There is increasing evidence that a notable proportion of household consumption is wastage, a recent study showed that for one water company wastage makes up 9% of household consumption in unmetered properties. Another important finding is that even when we remove continuous flow and wastage from the household consumption there are still huge consumers. High PHC values are not solely down to wastage and these high consuming properties need to be better understood.

In the recently reported collaborative project Artesia conducted into the summer of 2018, weather related consumption has also been shown to be been extreme and far from normally distributed. Some properties remain quite constant over the summer period and others have considerable use which impacts their overall annual consumption. Water use in the garden can consume huge volumes, whilst water use events within the home are somewhat restricted. Most within home events are for a specific purpose (other than wastage), they have known volumes well estimated/quantified frequency of use. Outside use is much less constrained, and nowhere near as well understood. The work we did on outside use for the 2018 peak project stated to quantify the length and volume of external use events. The findings were that these outdoor use events were high volume and highly variable, but we did not attempt to quantify or explore the different types of water use.

The final “cause” of the right-hand tail mentioned is less of a direct cause, but it is important to mention metering. Being on a meter or not does not causes extreme use, but metering either through optants or bill comparisons does leave a particular group of high users that actively avoid going onto a meter. As meter penetration increases the remaining pool of properties begin to be the abnormal rather than in a low meter penetration scenario where the optants tend to be the abnormal group. Our work with companies assessing individual household consumption with Thames, South West Water and the collaborative peak project have all demonstrated this. Wastage, external use and general extreme use is more common in unmetered properties than metered. These extreme uses all occur within measured households, but the prevalence, magnitude and frequency of these extreme events are reduced. Metering allows the customer to see the volume of water they use. Leaving a hosepipe running comes with a cost, or at least an associated volume to the customer as well as the water company.

4. HOW TO TARGET THE RIGHT-HAND TAIL

In this section we present findings from a 2-year project with Southern Water which sought to identify the most cost-efficient households for household water efficiency visits. These visits, which involve contractors visiting households to install water efficient devices and provide behaviour change advice, are a major part of the industry’s water efficiency efforts for the next five years.

In this project, we identified target households based on a model which used household consumption and other information about the property. The effectiveness of this model was tested by carrying out water efficiency visits at the properties identified, and across the range of modelled water efficiency rankings for each property. We then compared their water consumption before and after the visit and assessed the model against the savings made on a property by property basis. Southern Water have a great advantage for targeting households in this way, because of their meter penetration being at over 90%. The water saving targeting model has been shown to be effective, and we have found some useful insights into the practicalities of this type of targeting.

Our biggest learning is that regular meter reads, whilst not vital for creating an effective model, or for engaging with customers to get a home visit, are crucial for gaining further insights and being able to fully capture the savings made at these visits. Within property consumption, as already stated is extremely complex and highly variable at a property level. Seasonality and outside use, occupancy changes, wastages and other large and unpredictable consumptions mean that six-monthly data captures all sorts of other impacts as well as the impact we are trying to measure. In terms of annual PCC targets a bigger lead time to detect large consuming properties and wastage breakouts. This then means a lag to seeing these consumption reductions means that it could take up to a year to detect, fix and report a saving.

The method and modelling clearly works though. The targeting model is built not only on consumption data, but a range of other sociodemographic data and property data. The model is built to maximise savings, rather than to simply identify properties with high consumption. We expect certain properties to have high consumption, therefore it is important to account for what level of consumption we would expect in these properties. On top of this we expect certain people to be more receptive to home visits and water saving, but there are also certain types of properties or plumbing set up prevent water savings.

5. RECOMMENDATIONS

In summary, attacking the right-hand tail is important. Most properties already use a modest amount of water. It is important that water companies identify this and start to communicate to customers that we expect them to use a modest amount of water rather than an average amount of water. Relatively few customers consume average, or greater than average amounts of water.

The best way to identify the right-hand tail is to meter the property. The consumption can be used by the customer or the water company to identify if water use is high. Individual property consumption data is the only reliable way to establish if a property has high consumption.

Preferably, use of smart meters with AMI will allow the information to be fed back to the water company quickly and efficiently.

Next, companies need to understand something about the property to establish if the property has higher than expected consumption, rather than high consumption. It is possible to model a group of households effectively, but property to property variability is extreme high and unpredictable. Therefore, we want to understand which properties have a consumption higher than their estimated consumption.

To get the best impact from smart home visits, companies then target those properties by using a model to identify which properties are likely to save the most from a household visit. It is important to target those with higher than expect consumption – the right-hand tail, but if resource is limited then smart home visits should be targeted at those who are willing and able to save water, otherwise the home visit will be wasted resource.

Metering and home visits are independently effective in reducing household consumption. The combination of metering and analytics to identify the right-hand tail, followed by home visits, frequent meter reads and further analytics is our recommended approach to reducing household consumption.

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COMPETING INTERESTS

No competing interests.

REFERENCES

No references.

Portablecrac. A novel portable technology for the regeneration of granular activated carbon

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ABSTRACT

Activated carbon is a high adsorbent product employed for purification, deodorisation, and decolourisation in the chemical and water industries. Generally, the activated carbon, when saturated, is either disposed in a landfill or regenerated by thermal processes. Both practices involve a significant operational cost and negative environmental impacts. PORTABLECRAC (Portable Solution for the Electrochemical Regeneration of Activated Carbon) provides a successful business case to reduce overseas imports, energy inputs and greenhouse gas emissions. An electric potential difference is applied between two electrodes inducing the mobilisation of the contaminants. Thus, the original carbon properties are recovered. Compact and portable prototypes are designed and then tested in pilot plants in order to validate the technical and economic benefits of this technology. PORTABLECRAC brings a sustainable and long-term solution which pretends to improve flexibility and operation, create employment opportunities and reduce carbon waste as well as supporting the development of a circular economy.

Keywords: Regeneration, electrochemical, activated carbon, Horizon 2020.

1. INTRODUCTION

Nowadays, the chemical and water sectors require large amount of granular activated carbon (GAC) to remove contaminants from water and air. The GAC is produced from diverse carbonaceous source materials by a complex physicochemical process. In 2018, the global activated carbon market accounted for $6 billion [1]. Today, the demand trend still shows an exponential growth. Most of the activated carbon is manufactured overseas, mainly in China, and Europe imports about 80% of its internal consumption.

The unique adsorption characteristics of GAC depend on the specific surface area, pore structure and surface functional groups [2]. Due to continuous usage, the porosity becomes progressively saturated and inactive. In small facilities, when the carbon reaches its saturation limit, it is usually taken either to a landfill or to an incinerator. However, in facilities where a larger volume of carbon is used, the preferred option is to regenerate it through a thermal process. These practices are known to require off-site service, high energy input and carbon losses with significant environmental and economic impacts.

In this sense, PORTABLECRAC proposes the use of electrochemistry technology to regenerate saturated granular activated carbon in-situ. Though some studies reported on electrochemical regeneration of spent GAC, the present study attempts to develop a portable solution which pretends to improve the operational flexibility at a lower cost compared to current practices.

The initiative PORTABLECRAC belongs to the European Union´s Horizon 2020 Research and Innovation Programme. It has a total cost of 2.8M € and a duration of 36 months. The consortium consists of 5 organisations and 2 universities from 3 different European countries. The project is structured in three different packages which involve: the adaptation of current assets, design and fabrication of prototypes for the electrochemical regeneration; the

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investigation of the most appropriate treatment for the end-waste generated in the process; and finally, the development of prototype demos along with a technical and economical validation in order to access the market.

2. MATERIAL AND METHODS

The uniqueness of electrochemical method includes environmental compatibility, versatility, energy efficiency, safety, selectivity, amenability to automation, and cost effectiveness [3]. Narbaitz and Cen studied electrochemical regeneration of saturated GAC used for phenol adsorption and obtained more than 95% regeneration efficiency with no apparent carbon loss [4]. PORTABLECRAC is based on previous research done by the University of Alicante, in which the electrochemical regeneration of saturated GAC with toluene was achieved by 99% after 8 cycles using an electrochemical filter-press cell small prototype [5]. During the regeneration process, an electric potential difference is applied between two electrodes in a compartment filled with saturated activated carbon and electrolyte. As a result, the equilibrium between the adsorbed substances and the carbon pores is modified causing the detachment of these substances and therefore the recovery of the original carbon properties. The oxidation velocity is far less than that of desorption one affected by concentration gradient, resulting in the accumulation of organic matter in the electrolyte [6]. Therefore, the electrolyte receives the contaminants and progressively increases its concentration as it gets recirculated.

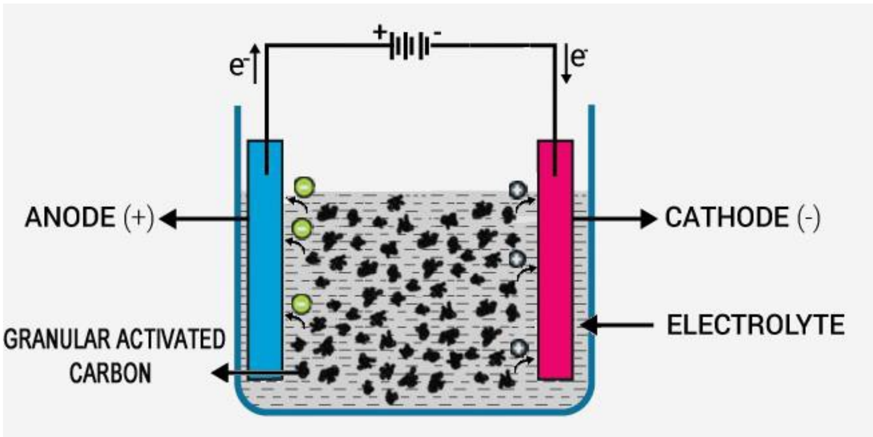

Figure 1. Example of an electrolytic cell

The electrochemical regeneration depends on different operating variables such as distance between electrodes; type, volume, concentration and renewal rate of the electrolyte; applied current intensity and density; and regeneration time. The regeneration time varies between 1 to 4 hours and the optimum tested electrolyte is composed by a sulphuric acid and water solution.

2.1 The prototypes

One of the main focus of the project falls on the creation of compact and portable devices which are capable to adapt to the customer´s regeneration needs.

The *Batch Prototype (A)* consists of two compartments with its corresponding electrodes attached and separated by a cationic membrane. Its design enables the option to optimise the amount of carbon to be treated which goes up to 100 kg. This discontinuous mode prototype is thought to provide service to facilities with low regeneration needs. *The Continuous Carbon Electro-Regeneration Prototype (B)* consists of two electrified belts combined with a bath of electrolyte. With its capability of operating in continuous mode it is expected to serve facilities with moderate regeneration needs. Finally, the *Vertical Prototype (C)* has been designed to operate in a semi-continuous mode. The unit is filled by a hopper and once the carbon is treated, it gets discharged from the lower part and so on. A modification of this design is expected to serve facilities with high regeneration needs.

A B C

Figure 2. Batch Prototype (A), Vertical Prototype (B) & Continuous Carbon Electro-Regeneration Prototype (C)

3. RESULTS AND DISCUSSION

Different types of granular activated carbon, in terms of granulometry, saturation status and application, have been considered in the project.

The following results represent the adsorption capacity and porosity recovery of an activated carbon regenerated in the Batch Prototype. The saturated activated carbon used for this test comes from a drinking water treatment plant in Valencia.

Table 1. Characterisation of the activated carbon by N2 at 77K and CO2 at 298K adsorption isotherms

Sample	S_{BET} ($m^2 \cdot g^{-1}$)	V_{DR} ($cm^3 \cdot g^{-1}$) N_2	V_{DR} ($cm^3 \cdot g^{-1}$) CO_2	V_{meso} ($cm^3 \cdot g^{-1}$)	RE
Pristine	950	0,33	0,17	0,09	100%
Saturated	750	0,28	0,14	0,08	79%
1h	820	0,32	0,16	0,09	86%
2h	815	0,31	0,18	0,09	86%
3h	850	0,32	0,17	0,08	89%
4h	870	0,33	0,16	0,10	92%

The table shows the recovery of the carbon surface area (S_{BET}) and the volume of micropores (V_{DR}) and mesopores (V_{meso}). The electrochemical regeneration efficiency (RE) of GAC can be calculated from the values of adsorption capacities of isotherm studies with pristine GAC and electrochemically regenerated GAC, i.e.:

$$RE = \frac{qmr}{qmi} * 100\%$$

where q_{mr} and q_{mi} are the adsorption capacities of the regenerated and pristine GAC of the same sample under identical adsorption conditions [7].

As it is observed, after 4 hours of treatment, the surface area is 92% recovered upon the pristine value. Also, the volume of micropores and mesopores is nearly 100% recovered.

The Figure 3. shows the adsorption volume against the relative pressure. As it is shown, the adsorption volume is partially recovered during the regeneration process obtaining, in this case, the best performance after 4 hours of treatment.

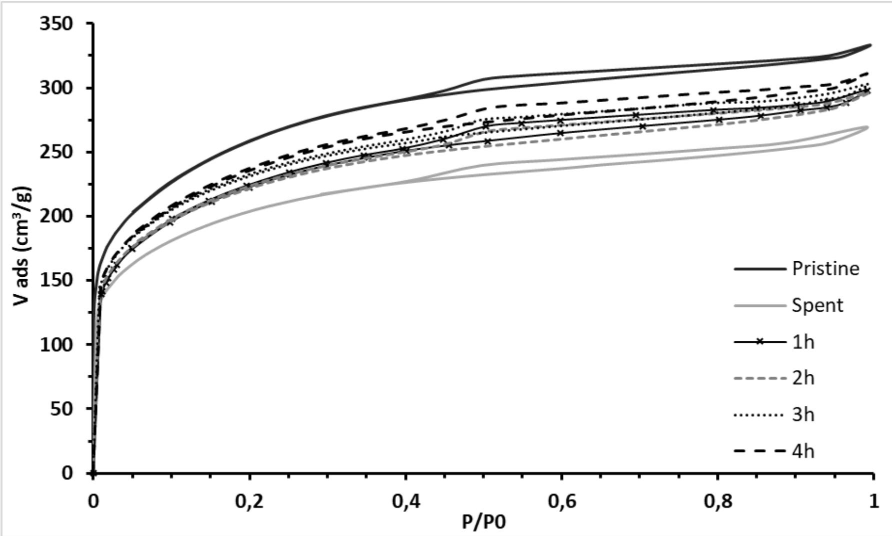

Figure 3. Langmuir adsorption isotherms

Concerning the increase of pollutants in the electrolyte and its disposal, different treatment solutions are currently being explored. The aim is to reduce the inorganic and organic load enabling either the reuse of the electrolyte or its discharge within the legal contents.

4. CONCLUSION

PORTABLECRAC is a flexible solution which allows an in-situ regeneration of activated carbon by portable and compact equipment capable of adapting to the client´s needs. It has been demonstrated the achievement of a specific surface area recovery greater than 85% with no carbon loss associated. In contrast, the thermal regeneration does not recover the surface area beyond 80% and carries a carbon loss up to 10%. The expected reduction of carbon footprint, the lower energy demand and the end-waste volume reduction will endorse the regional and European environmental requirements to help comply with the official directives approved by the European Union. Finally, it is foreseen that the technology leads to the creation of a new production line resulting in new jobs which will support the development of a circular economy.

ACKNOWLEDGEMENTS

The authors express their gratitude to the European Commission for funding the research and to the University of Alicante for sharing the data. Besides, it has been key the support received from the colleagues in La Presa Drinking Water Plant, from both laboratory and plant management.

COMPETING INTERESTS

All the prototypes will be registered and patented. The University of Alicante owns the rights for the business of the 100kg Batch Prototype and Global Omnium will be a member of the exploitation board.

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Don’t water down the whisky: Water scarcity footprint of single malt whisky production and by-product use

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ABSTRACT

Introduction: Spirit production is the number one water user within the UK drink manufacturing sector. However, smart use of distillery by-products, spent grains and pot ale, for the replacement of water intensive products, can significantly reduce the net water footprint of spirits such as whisky.
Methodology: We apply the AWARE (Available WAter REmaining) methodology to conduct a Life Cycle Assessment-based water scarcity footprint of the production and by-product use of Scottish single malt whisky in order to a) identify the best option for by-product use from different feed use and bioenergy scenarios and b) quantify the reduction potential of whisky’s water scarcity footprint.
Results: Assuming that barley in the UK is a rain-fed crop, distillery operations account for approximately half of the water scarcity footprint with a hotspot being cooling water. Barley cultivation mainly requires water indirectly through water consumed for producing fertilisers. The water scarcity footprint of whisky can be reduced by up to 19% through the use of by-products a) as direct animal feed replacing domestic barley and imported soybean meal and b) for biogas generation with subsequent combustion in a CHP plant and digestate application as fertiliser.
Conclusion: in terms of water scarcity, there is no clear benefit for the use of by-products for renewable energy purposes, in contrast to it being the government incentivised option. The greatest water footprint reduction can be achieved through both, feed and bioenergy use, ideally combined with process optimisations in the distillery, such as installation of a closed cooling water loop.

Keywords: water scarcity footprint, LCA, distillery by-products, whisky, feed, biogas, fertiliser

1. INTRODUCTION

Spirit production is the number one water user within the UK drink manufacturing sector. Responsible for 60% of the sectors water use, it accounts for more than that of other alcoholic beverages and soft drinks together [1]. In Scotland, malt distilling for whisky is the second biggest water user within the whole manufacturing sector, only surpassed by abstractions for fish farming, and is before the water intense paper industry [2].
Although estimates exist for the volume of water used in distilleries, less research has been

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undertaken on the contributions to water scarcity. Scotland and the UK as a whole are certainly not perceived as water scarce, but especially in the south and east of England over-abstractions of water bodies do occur regularly, and half of the agricultural holdings abstracting 85% of irrigation water in the UK are located in catchments where no more water is available [3]. The water scarcity issue becomes yet more interesting when local production, e.g. of distillery by-products, can replace imported products grown in countries facing even more limited water availability.

By-product use from malt distilleries has a long tradition in Scotland, where it has probably been fed to cattle and sheep for more than 500 years [4]. Recently though, a shift from feed to bioenergy use has been observed, as incentives by the UK and Scottish government for renewable energy technologies have been taken up by the distillery sector [5]. Though energetic use of by-products brings benefits for a distillery's carbon footprint, from a water use perspective, feed use also deserves recognition as environmentally favourable, when the protein rich by-products replace imported feed such as soybean meal.
It is the aim of this study to assess the impacts of the production of malt whisky on water scarcity by:

- Calculating the water scarcity footprint for Scottish single malt whisky
- Identifying the water consumption hotspots within the life cycle of whisky production
- Exploring the reduction potential for the water scarcity footprint through different by-product uses including for feed, energy generation and as fertilisers.

Previous studies on life cycle impacts of spirit and whisky production have focused on greenhouse gas (GHG) emissions and other environmental impacts such as eutrophication, acidification or fossil resource depletion [6–8] or included water use only in volumetric terms, overlooking scarcity [9]. This might be partially due to water scarcity assessment being a fairly new method. A consensus based methodology for Life Cycle Assessment (LCA)-based water scarcity footprint was only published by the LCA community in 2018 [10] and the developed AWARE (Available WAter REmaining) method is now the officially recommended method by the Life Cycle Initiative of UN Environment, the Product Environmental Footprint of the European Commission, and other institutions [11]. The AWARE method was therefore chosen for the water scarcity footprint in this study.

2. METHODOLOGY

The water scarcity footprint follows the guidelines of a Life Cycle Assessment, i.e. encompasses all raw materials and processes necessary for the production of whisky and the management of waste and by-products (Figure 1). The functional unit is 1 litre of pure alcohol (LPA, 100% ethanol) of unpackaged single malt whisky, with empiric process data provided by Arbikie Distillery on the East Coast of Scotland.

2.1. Description of the system

2.1.1 Distillery processes

Single malt whisky is made from barley malt and the process starts, following milling, with mashing, the mixing of barley malt with hot water to solubilise the starch and degrade it to sugars ready to be fermented by yeast in the next step. At Arbikie distillery, 600 kg barley malt are mixed with about 6400 L water, increasing from an initial slurry temperature of 64°C to a final temperature of 94 °C. Other than in grain distilling, the spent grain is already separated from the remaining liquid, the wort, immediately after mashing. Following fermentation, the fermented wort, now called beer wash, is distilled twice, and yields an approximately 70% strong new make spirit which, after cask maturation, would become single malt whisky (maturation is not considered in this study). The by-product from the first distillation is the pot ale, which still contains a useful amount of dry matter. As mainly the carbohydrates of the barley are consumed for whisky production, both spent grain and pot ale are naturally rich in proteins, and especially the yeast containing pot ale offers a "good amino acid balance" for feeding [4]. The leftover from the second distillation, the spent lees, are predominantly water, and can be discarded. Water and heat requirements in spirit production are high, with approximately 130 L per LPA produced in this study. Water is not only required for mashing, in fact, the majority of water is evaporated in the cooling tower and used for steam production, including steam used for wash preheating via direct steam injection. The high consumption of cooling water is typical for a distillery and it is estimated that 90% of the water used by Scottish distillers is for cooling [2]. A minor amount of water is used for cleaning of equipment and facility. Arbikie distillery supplies most of the water through its own borehole and a smaller part through mains water supply, also this being standard amongst most malt distillers [2]. For further process information, see Table 1.

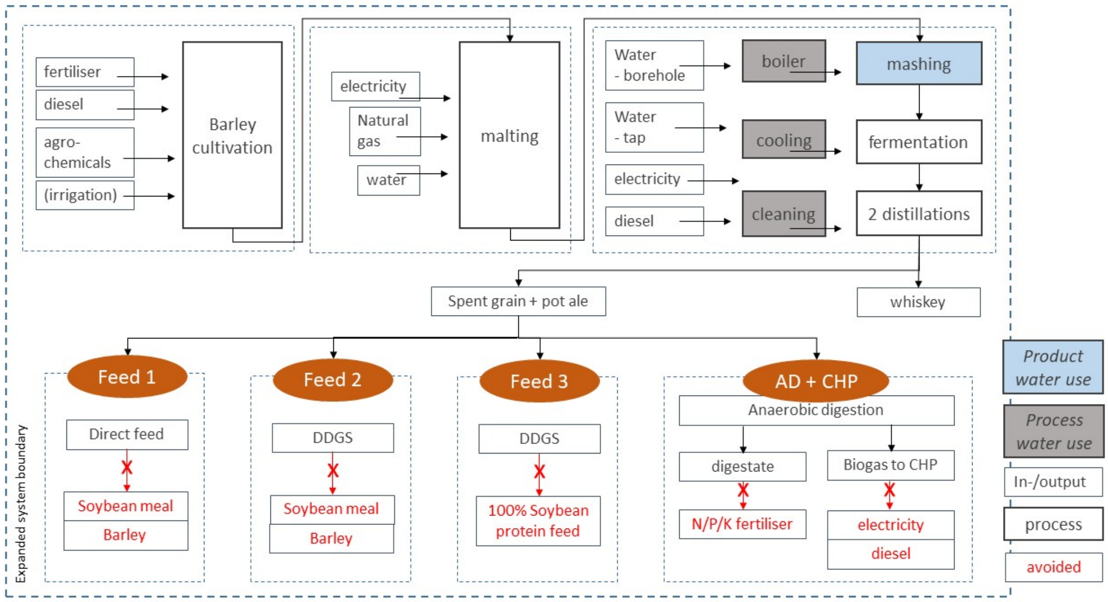

Fig. 1. Overview of main processes, inputs and outputs accounted for in the water scarcity footprint of single malt whisky. The by-product scenarios (use of spent grain and pot ale) are alternative to each other. DDGS = Dried distiller's grains with solubles

2.1.1 By-product use

By-products from Scottish distilleries are commonly used for feed purposes or as a source for renewable energy. We examined the influence of the type of use on the water scarcity footprint of whisky through four different scenarios:

- Feed 1: direct use of fresh spent grain and pot ale on a nearby farm as cattle feed. Replacing: Soybean meal and barley
- Feed 2: direct use of spent grain and pot ale processed to dried distiller's grains with solubles (DDGS) on a nearby farm as cattle feed. Replacing: Soybean meal and barley
- Feed 3: spent grain and pot ale to DDGS. Replacing 100% protein soybean feed on a nearby farm as cattle feed
- AD + CHP: anaerobic digestion (AD) of by-products, combustion of biogas in combined heat and power (CHP) plant, and application of digestate as fertiliser. Replacing: Heat, electricity, fertilisers

Spent grain and pot ale can be directly fed in their wet form or processed to dried distiller's grain with solubles (DDGS) which conserves it and reduces its weight, allowing for longer storage and transport and thus making its use more flexible. Because of their high protein content, both are suitable replacements for imported soybean-based feed, but also come with an additional energy content. To replace an equal amount of both crude protein and metabolisable energy, the replacement of a combination of imported soybean meal and the domestic energy crop barley is considered. As in Lienhardt et al. [8] and Leinonen et al. [7] the quantities were determined via linear optimisation, using the Excel solver function, keeping an equal protein and energy content while maximising the amount of feed replaced based on the dry matter content of the by-product. Only in the Feed 3 scenario, solely the protein part of DDGS is replaced. Crude protein and metabolisable energy content of the by-products were obtained from Feedipedia [12].
The renewable energy scenario looks at the anaerobic digestion of the by-products to produce biogas which is subsequently burned in a CHP plant to generate heat and electricity to replace the heating fuel used in the distillery as well as grid electricity. When calculating the amount of

available surplus energy from biogas combustion, we take into account leakage rates for the digester and the CHP plant, as well as the energy consumption for the digester itself (Table 1). As the digestate left from biogas production contains significant quantities of nitrogen, phosphorus and potassium, it serves as a replacement of inorganic fertilisers. The MANNER-NPK tool [13] was employed to determine the fertiliser amount replaced, assuming digestate application through shallow injection, onto a sandy clay loam soil and application during March, June and September. This resulted in an average crop availability ratio of 55, 50 and 89% of the applied nitrogen, phosphorus and potassium, respectively. The available nitrogen amount in the digestate is corrected by losses of NH_3-N during digestate storage (Table 1).
The use of by-products is treated with a system expansion approach, following previous studies on spirit production by-product management [7,8]. The distillery system is expanded to include the use of the by-products and the products they replace. I.e., replaced soybean and barley feed, as well as replaced electricity, heat energy and fertilisers are added to the whisky system in order to display the benefits from avoided products. They are shown as negative values in the results, reducing the water scarcity footprint of the whole system.

Tab. 1. Inventory for modelling the production and by-product use of Scottish single malt whisky. LPA = litre of pure alcohol; DM = dry matter, ME = metabolisable energy (ruminants); DDGS = dried distiller's grains with solubles

Process/material	Quantity	Reference/comment
Barley and malting		
Water barley irrigation per t barley	48 L	[14]
Barley grains per kg malt	1.19 kg	Average of three malting facilities
Water per kg malt	5 L	Average of three malting facilities
Thermal energy per kg malt	2.77 MJ	As natural gas
UK grid electricity per kg malt	0.123 kWh	Average of three malting facilities
Distillery		
Barley malt per LPA	2.68 kg	Process data distillery
Water for mashing per LPA	18.8 L	Process data distillery
Water for cleaning per LPA	2.07 L	Process data distillery
Water for cooling per LPA	65.7	Process data distillery
Water for steam boiler per LPA	42.7	Process data distillery; Part is consumed during wash preheating as direct steam injection
Water from borehole	86%	Process data distillery; Remaining water is tap water
Thermal energy per LPA	26 MJ	Process data distillery; As diesel
UK grid electricity per LPA	1.17 kWh	[8]
Spent grains per LPA	3.02 kg	Process data distillery; From mashing
Pot ale per LPA	6.31 L	Process data distillery; From 1st distillation
Spent lees per LPA	2.94 L	Process data distillery; From 2nd distillation. No significant dry matter content [4].
Spent grain dry matter	28%	Process data distillery
Pot ale dry matter	5%	[4]
Feed scenarios		
DDGS production:		
DDGS produced per LPA	1.07 kg	Process data distillery
DDGS dry matter	90.7%	[12]
DDGS crude protein	28% DM	[12]
DDGS ME	12 MJ/kg DM	[12]
Thermal energy per LPA	0.594 MJ	Based on [15]
UK grid electricity per LPA	0.014 kWh	Based on [15]
Avoided feed:		
Avoided soybean meal per LPA (Feed 1, Feed 2)	0.365, 0.376 kg DM	
Soybean meal dry matter	88%	[12]

Soybean meal crude protein	55%	[12]
Soybean meal ME	13.4 MJ/kg DM	[12]
Avoided barley per LPA (Feed 1, Feed 2)	0.628, 0.536 kg DM	
Barley dry matter	87.1%	[12]
Barley crude protein	11.8%	[12]
Barley ME	12.4 MJ/kg DM	[12]
Avoided soybean protein feed (Feed 3)	0.271 kg DM	
Soybean protein feed dry matter	89%	[16]
Soybean protein feed crude protein	99% DM	[16]; Considering fat content less than 1.3% of dry matter.
AD + CHP Scenario		
AD + CHP specifications:		
cumulative methane yield	355 L/kg DM	[17]
Digester methane leakage	1%	[18]
CHP combustion methane leakage	0.5%	[18]
Usable energy of methane (electricity)	30%	Efficiency CHP plant: 70%; [19]
Usable energy of methane (heat)	40%	Efficiency CHP plant: 70%; [19]
Avoided electricity and heat:		
Avoided electricity per LPA	1.09 kWh	Energy requirement for AD plant considered.
Avoided thermal energy per LPA	4.57 MJ	Energy requirement for AD plant considered.
Avoided fertiliser:		
NH_3-N leakage rate from digestate storage	2%	For closed tank storage [18]
Avoided N per LPA	21.5 g	As ammonium nitrate. Based on [12] and [13]
Avoided P (P_2O_5) per LPA	4.08 (9.35) g	As triple superphosphate. Based on [12] and [13]
Avoided K (KO_2) per LPA	6.45 (7.78) g	As potassium chloride. Based on [12] and [13]

2.2. Water scarcity footprint – theory and application

The focus of this study is the impact of whisky production and by-product use on water scarcity determined with the AWARE methodology [10]. The AWARE methodology provides the characterisation factors (CF) which are multiplied with the amount of water consumed by a certain process or product and which leads to a water scarcity footprint (=impact on water scarcity). The factors represent the water scarcity in a geographic area (watershed) and defined time (month) based on the amount of available water remaining after human and aquatic ecosystem demand have been met. It assumes a direct proportionality between the amount of water consumed and the potential to deprive another user of water. In contrast to some other water footprint assessments, the AWARE approach is based on water consumed, i.e. only the water abstracted and used which does not return to the same watershed after use but instead gets incorporated in a product, or – e.g. in case of irrigation – is lost through evapotranspiration by soil and plants. Also in the distillery case, not all water withdrawn is lost for the watershed. The water from cleaning and spent lees is assumed to be released at the distillery site and therefore displayed as negative water scarcity contribution in the results section. Similarly, the water content of directly used spent grain and pot ale (scenario Feed 1) as well as the water in the digestate (scenario AD+CHP) are displayed as negative values as they are assumingly used at a nearby farm.

The regional variability of water scarcity is an essential difference to other environmental impacts usually addressed in a Life Cycle Assessment. Other than in the case of e.g. global warming where the effect of a molecule of CO_2 is independent from the geographic area of its emission, in water scarcity assessment, the location of a water consuming activity is essential as water availability and consumption by humans and ecosystems can be regionally very different. The regional aspect requires a high amount of data for the determination of the characterisation factors, but also for water footprint practitioners. Although AWARE characterisation factors have been provided for over 11,000 watersheds worldwide on a monthly scale, average country-wide and yearly factors are commonly used [20]. In order to partially overcome inaccurate water footprints where no information on the watershed is available, sector-specific factors distinguishing between agricultural (agri) and non-agricultural (non-agri) activities have been provided; and another alternative approach is the use of crop-specific factors [20]. Nevertheless, due to the very recent evolvement of the AWARE methodology and its characterisation factors, LCA databases such as Ecoinvent [16] and with it modelling software such as Simapro [21] which were also used for this study, currently do only support the use of country and yearly averaged CFs.

2.3. Data sources and modelling

The process data on whisky production in the distillery were obtained directly from the Scottish distillery Arbikie, while data on inputs for malting represent average values from three UK malt houses (confidential data). Data for modelling by-product management and background processes were taken from the literature and Ecoinvent database [16] (Table 1).

Regional differences in water scarcity complicate the use of generic database processes for modelling of the background system in a water scarcity assessment. The use of proxy processes such as European average processes for the cultivation of barley or the production of tap water can greatly alter the result of a water footprint intended to be for a more specific area, such as the UK in this study. Therefore, adjustment of background processes not originally designed for the UK is necessary. The cultivation of barley is based on the process for France, but the origin and amount of water have been adjusted for the UK. Ecoinvent's water inventory flows for crops are based on the database developed by Pfister and colleagues, comprising blue water consumption values for 160 crops [14,22,23]. To be consistent with the remaining water inventory flows in Ecoinvent, the same source was taken for water consumption (irrigation) for barley cultivation in the UK, resulting in 48 m^3/t barley. But, as typically less than 0.3% of cereal areas in the UK are irrigated [24] and as barley isn't irrigated at the Arbikie farm from our study, we also use the case of no barley irrigation for comparison of results.

In the case of drinking water production, Ecoinvent's European tap water process considering treatment through coagulation, decantation and chlorine disinfection [16], was modified to contain water of UK origin and further parameters listed in Table 2.

Tab. 2. Modifications of European tap water process from Ecoinvent database to represent the UK case

Specifications tap water UK:	Quantity	Reference
Leakage rate [%]	17	[25]
Groundwater [%]	30	[26]
Surface water [%]	70	[26]
Electricity consumption [kWh] per L supplied	0.00059	[27]

3. RESULTS AND DISCUSSION

Figure 2 shows the results of the water scarcity footprint obtained with the AWARE method, detailed for malting, distillery operations and the scenarios for spent grain and pot ale use. Barley cultivation (not shown in the graph) accounts for a water scarcity footprint of 0.45 m^3 (rain-fed barley) and 1.0 m^3 (irrigated barley). For whisky from rain-fed barley, distillery operations cause the highest water footprint with 52%, followed by barley cultivation with 42%. For irrigated barley, the largest part of the water scarcity footprint of whisky making, excluding by-product use, is caused through the cultivation of barley with 62%. The water consumed for barley cultivation is not only potential irrigation, but also comprises water for the production of the N-fertilisers urea and ammonium nitrate, as well as phosphate fertilisers. Within the distillery, the hotspot is cooling water for cooling of the mash before fermentation and the distillate. The cooling water makes up for about half of the water supplied to the distillery and contributes to 40% to the water scarcity footprint of the distillery alone. It is followed by the water used for steam generation, which is partially lost, and partially becomes part of the product as it is also used in wash preheating. Electricity consumption is contributing to water scarcity due to evaporation of cooling water in nuclear, gas and coal power stations. With the future grid mix likely to contain less fossil fuel power stations, this part of the water scarcity footprint is expected to decrease.

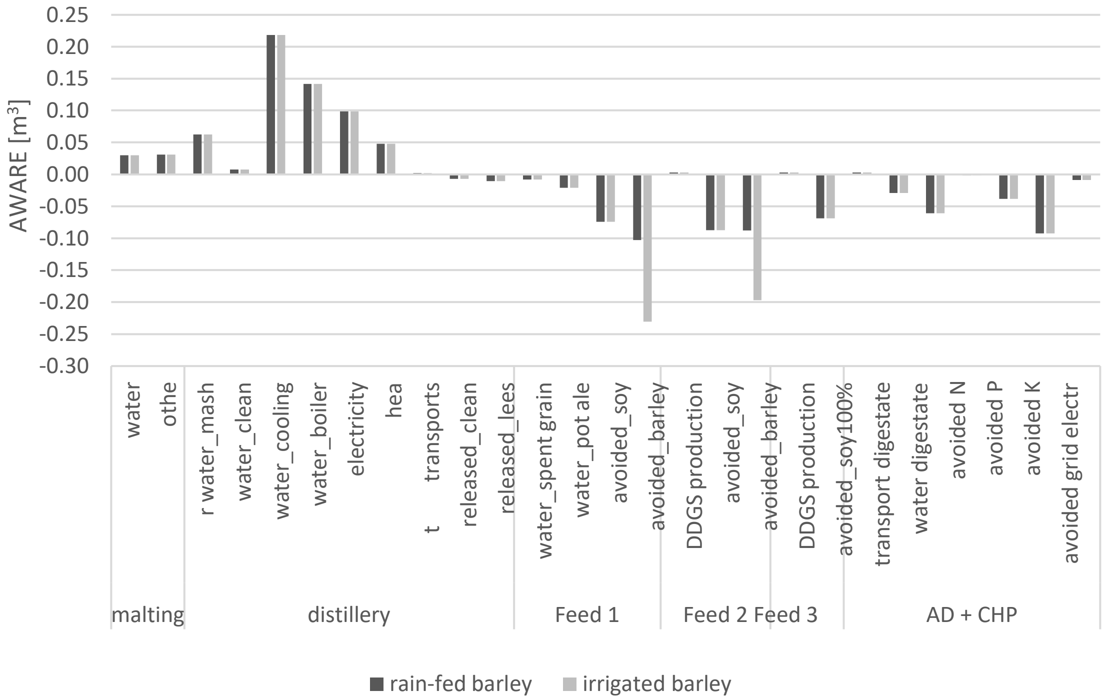

Fig. 2. AWARE Water scarcity footprint of 1 LPA single malt whisky split in: malting, distillery operations and scenarios for by-product use (barley cultivation not shown). Negative values show water released into the same watershed (water from cleaning, spent lees, spent grain, pot ale and AD digestate) or avoided water consumption from replaced products (avoided soy and barley feeds, N/P/K fertiliser, grid electricity and heating fuel). Malting (other) = heat, electricity, transport.

Feed scenario 1 and 2 both achieve higher savings through avoiding barley, than soybean meal, which can be explained through the higher amount of barley being replaced, as the AWARE footprint for the soybean meal mix available on the global market is 0.20 m^3/kg, while the one for UK barley is 0.14 (no irrigation) and 0.32 (irrigation). The soybean originates mainly from the USA, Brazil and Argentina. Also in Leinonen et al. [7] higher amounts of barley could be replaced than soybean meal. Feed 3 scenario offers a smaller savings potential, as only soybean protein feed is replaced. The additional footprint through energy and heat used in DDGS production is marginal compared to the avoided footprints. In the AD+CHP scenario, the greatest impact is avoided through the replacement of grid electricity from biogas combustion, as well as the avoided N-fertiliser ammonium nitrate.

Figure 3 shows the summarised results of the AWARE footprint per scenario, split into incurred and avoided impacts, and as total footprint. In the case of rain-fed barley the biogas and direct feed scenario (AD+CHP and Feed 1), provide the greatest benefits with 19 and 17%. In the case of irrigated barley, the use of the by-products as direct feed and DDGS replacing soy and barley (Feed 1 and 2) offer the greatest and similar water footprint reductions with 19 and 17%, respectively. In both cases, direct feeding of by-products without drying to DDGS is preferable from a water perspective, as evaporated water from DDGS production is accounted for as lost for the watershed. The smallest total water scarcity footprint is achieved for 1 LPA whisky made from rain-fed barley and AD+CHP with 0.84 m^3. If barley irrigation is assumed, Feed 1 scenario achieves the lowest water footprint with 1.3 m^3. It shows that in terms of water scarcity, there is no clear benefit for the use of by-products for renewable energy purposes, in contrast to the suggested reduction of GHG emissions through the government incentivised bioenergy option. The water savings are partially “invisible”, indirect savings though, achieved outside the distillery or even abroad and therefore do not directly improve a distillery’s footprint.
Similar observations have been made by Leinonen et al. [7], who conducted an assessment on GHG emissions from different by-product use scenarios from single malt whisky: in terms of percentage reduction of burdens through by-product use, higher reduction was achieved when by-products were used as feed with DDGS, replacing soybean and barley feed (40%) than through renewable energy use and digestate application (27%). Again, these were partially indirect savings connected to land use change for the cultivation of soy abroad.

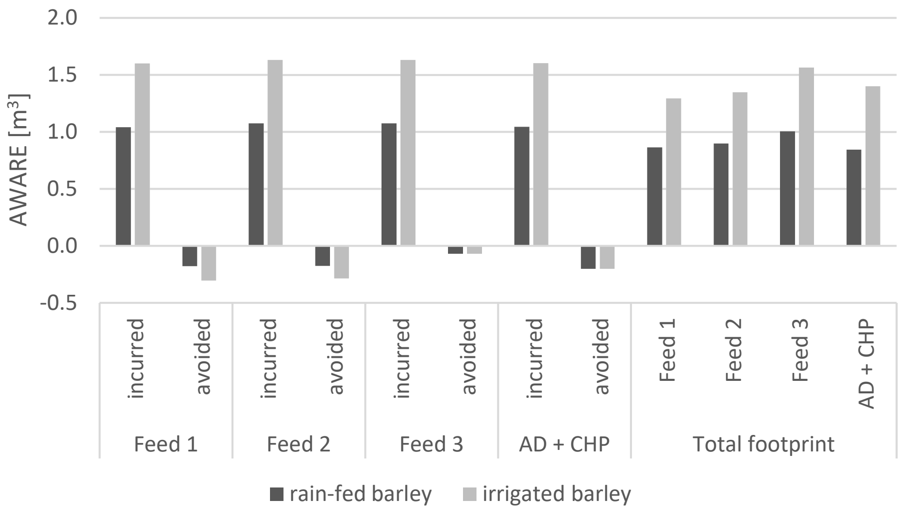

Fig. 3. Left: AWARE water scarcity footprints for 1 LPA single malt whisky split in incurred and avoided impacts per scenario. Incurred impacts are the summarised impacts from barley cultivation, malting and distillery stage as well as additional impacts from transports or DDGS production. Right: Total AWARE footprints summarising incurred and avoided impacts for each by-product use scenario.

Although great care has been taken in choosing and modifying background processes from the Ecoinvent database to achieve an accurate AWARE footprint, results not based on the reliable primary distillery data still exhibit considerable uncertainty and total scenario results have therefore to be interpreted with care. Limitations in application of the methodology are caused through a) limited regionalisation of processes in commercial databases such as Ecoinvent: process inputs do not refer to the UK, e.g. barley cultivation or tap water, b) the limited accuracy of water inventory flows for crop irrigation in general in LCA databases and underlying blue water consumption data sets [14,22] and c) the current unavailability of agri/non-agri and crop-specific characterisation factors in databases and modelling software. These issues reflect the fact that AWARE and other water footprinting methodologies are still relatively new compared to other LCA impact categories and also due to the high amount of data required as it is a regionally varying footprint.
Nevertheless, certain recommendations for the reduction of the water scarcity footprint of Scottish single malt whisky can be drawn from this case study. The results show that especially water and energy saving measures within a distillery have the potential to contribute to a lower

footprint. The biggest benefit could come from the installation of a closed loop cooling water system, avoiding the evaporation of cooling water in a cooling tower completely and saving about 50% of water used in the distillery alone. Instead, surplus heat could be used to heat the mashing water and the stills, saving heating fuel at the same time. In order to give a final recommendation on by-product use, modelling constraints mentioned above and further research in the location (watershed) of water released from the by-products would be necessary. With the above results though, both feed and bioenergy use of distillery by-products are equally valuable options to reduce the water scarcity footprint of whisky.

4. CONCLUSION

This study was to our knowledge the first to assess the water scarcity footprint based on the AWARE methodology of Scottish single malt whisky including barley cultivation, distillery operations and different scenarios for the use of the by-products spent grains and pot ale. The following conclusions can be drawn:

- For whisky from rain-fed barley, distillery operations contribute most to the footprint for whisky with hotspots being cooling and boiler water, followed by barley cultivation, with hotspots being water for the production of fertilisers.
- By-product use as feed and for renewable energy generation can reduce the footprint by up to 19% and reduce it to 0.84 m^3 per LPA (for rain-fed barley), hence there is no clear benefit from using by-products for bioenergy production instead of feed.
- The water footprint of the distillery operations could be greatly reduced through a closed cooling water loop and heat recovery.
- Full implementation of the AWARE method with current databases and software is still limited
- Further accuracy and regionalisation of water inventory flows of crops and other background processes is needed to enhance reliability of results.

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COMPETING INTERESTS

None.

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Air temperature influence on hot and cold water consumption in dwellings

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ABSTRACT

Countries around the globe are moving efforts towards decarbonized societies, namely by taking actions to reduce energy consumption and to increase the share of renewable energy sources at the building stock level.

Understanding domestic hot water consumption drivers is a key requirement for optimizing the design of innovative control strategies based on consumption patterns and the design of solar-thermal-hot water-systems, as well as to help develop solar-thermal-incentive programs.

In this study, the influence of air temperature on domestic hot and cold water consumption in two climatically distinct countries, Belgium and Portugal, has been analysed. The dataset from Belgium consists in monthly consumption records of hot and cold water in 9,200 apartments from 480 buildings, while the dataset from Portugal, of a single apartment, comprises high-resolution data, with an acquisition frequency of 20 records per minute.

An air temperature influence was found in both datasets: in cooler periods the proportion of hot water consumption increases, whilst in warmer periods decreases.

Keywords: domestic hot water, residential water consumption, air temperature, decarbonisation, energy efficiency, renewable energy

1. INTRODUCTION

The 2030 climate and energy framework set by the European Commission defined three minimum key targets for 2030, relative to the 1990 levels [1]: i) reduce greenhouse gas emissions (GHG) by 40%; ii) increase energy efficiency by 27%; and iii) increase the contribution from renewable energy sources to 27% of the final energy consumption.

In the European Union (EU), almost 50% of the final energy consumption is used for heating and cooling, of which 80% is used in buildings [2]. Although, for the residential sector, space heating is, on average, the most important end-use in the residential sector (68%), the second most energy consuming end-use is water heating, with differences from country to country. In Italy, Poland, Belgium and Luxembourg, the share of space heating is above 70% and in Malta, Portugal and Cyprus it is below 30%. The average share of energy consumption for water

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heating in residential buildings is 15% in the EU and, although less variable, it still ranges from around 8% in Bulgaria, Croatia and Greece up to around 25% in Cyprus and Malta of the total energy consumed [3]. In the USA and Australia the situation is similar, with water heating attaining about 18% of the total energy consumed in residential buildings in the USA and 23% Australia [4], [5]. On the other hand, it corresponds to 40% of the total energy consumed in residential buildings in China [6].

As such, buildings are central players in the implementation of energy efficiency and decarbonization policies. The Energy Performance in Buildings Directive (EPBD) recast (Directive 2010/31/EU), revised by the Directives 2016/1318/EU and 2018/844/EU, requires that by 31 December 2020 all new buildings are nearly zero-energy buildings (NZEB) and that the existing building stock should be renovated to move towards its transformation to NZEB to contribute to the long-term climate change target of 80-95% greenhouse gas emission reduction in the European Union by 2050 (compared to 1990). An NZEB is “a building that has a very high energy performance…” and its “nearly zero or very low amount of energy required should be covered to a significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby” [7-9].

In this regard, achieving a detailed characterization of the domestic hot water (DHW) consumption patterns is of great relevance, as this information will allow for the design of innovative control strategies based on consumption patterns [10] and for the solar-thermal-hot water-system designers and the policy makers supporting solar-thermal-incentive programs [11].

Metering is different from country to country. Millock and Nauges [12] used survey data from around 10,000 households in 10 OECD countries, observing that 63% of the households were charged and metered for their water use, 13% were charged a flat fee (not metered) and 24% were not charged at all for their use of water. This situation makes it difficult to, in a large number of situations, access to data on domestic hot and cold water consumption. In addition, even when meters exist to track hot and cold water consumption, the split per end-use is unknown, contributing to explain the launch of a large number of measuring campaigns on cold and hot water consumption in buildings [13-18].

In this regard, the purpose of this study is to analyse the influence of air temperature on residential hot and cold water consumption, in order to contribute for the knowledge on the behaviour of DHW consumption.

2. METHODS

2.1 Measured data

Two case studies involving different climates and domestic hot water supply contexts are explored in this study. The first refers to monthly total hot and cold water consumption data of 9,200 apartments from 480 buildings located in Belgium, around Brussels, Flanders and Wallonia, over a period of up to 3 years, for each building, between 2008 and 2012. The second refers to hot and cold water consumption, disaggregated per device, and acquired every 3 seconds in a bathroom of an apartment located in Aveiro, Portugal, between September 2018 and February 2019, during 163 days.

In the first case water is heated at the level of the building and thus hot and cold water consumption data were made available through metering. In the second case the dwelling is equipped with a gas-fired boiler, so metering exists only for cold water. For this reason, the acquisition of data was performed in two different ways: i) monitoring water consumption; and ii) voluntary water consumption track. Monitoring water consumption was performed with the help of a *Fluxus® F601* ultrasonic flowmeter, connected to two different sensors that measured simultaneously cold and hot water consumed in the bathroom, with an acquisition frequency of 20 records per minute. The flowmeter measures volumetric flow rate with an uncertainty of ±1% of reading at the measuring point (±0.005 m/s of the flow velocity) and a repeatability of 0.15% of reading (±0.005 m/s) and allows the detection of flow velocities in the range 0.01-25 m/s. In order to test the accuracy of the flowmeter for the studied conditions, several measurements in a washbasin tap and in a showerhead, both in laboratory and real conditions, were compared with the volumetric method, presenting very similar results. Tracking water consumption was performed through voluntary filling of a questionnaire, where the user identified the appliance used and the time of use.

2.2 Analysis of measured data

In the Belgian case study the initial sample comprised of cold and hot water monthly records between 2008 and 2012 from more than 10300 apartments spread over nearly 500 buildings divided in terms of location by Brussels, Wallonia and Flanders. The dataset was subject to a cleaning procedure to remove the cases with: i) lack of cold or hot water measurements; ii) less than one year of records; and iii) incompatible hot and cold measurement dates. The cleaned dataset was reduced to 9,200 apartments from 480 buildings with the spatial distribution depicted in figure 1.

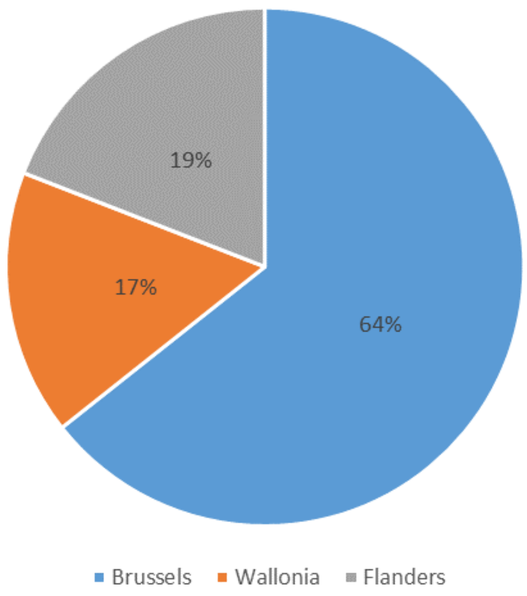

Fig. 1. Spatial distribution of the dataset in the Belgian case study

The water consumption was measured continuously for 1-3 years in each apartment in the period between 2008 and 2012. A large portion of the apartments (4,200) has 3 years of measurements, 4,900 have between 2 and 3 years and only 43 have between 1 and 2 years of records. The period with the highest number of records was between the second semester of 2009 and the first semester of 2012.

Complementarily, the monthly average air temperature in Brussels was also obtained for the period between 2008 and 2012 from the Brussels airport station.

Connecting the monitored water consumption data with the voluntary water consumption track, in the Portuguese case study, allowed to identify the specific water consumption pattern associated to each bathroom appliance and disaggregate the water consumption by appliance for the total, hot and cold water consumed (figure 2).

Since the consumption of hot water in the other appliances was marginal, this study focuses only on data from the showerhead.

The daily average air temperature in Aveiro was also obtained for the period between September 2018 and February 2019 from the University of Aveiro station.

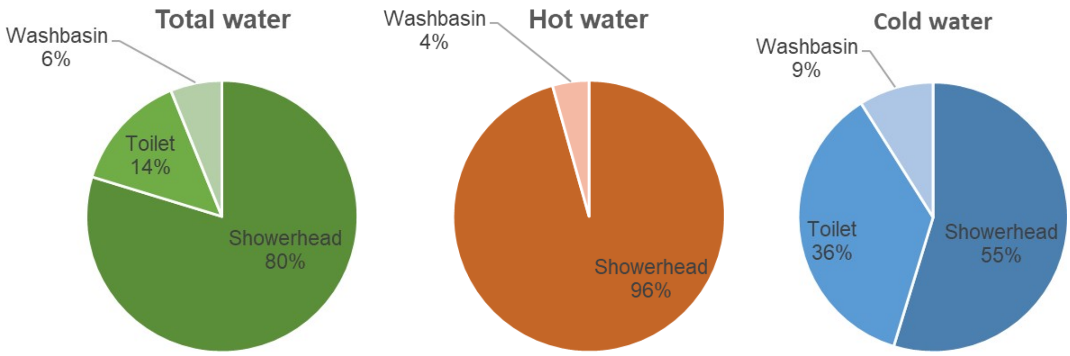

Fig. 2. Total, hot and cold bathroom water consumption by end-use

3. RESULTS

Figure 3 presents the evolution of the relative daily water consumption per month (daily water consumption in month i of year j / average daily water consumption in year j), for the Belgian case study, and air temperature. The air temperature profile was estimated as the average daily temperatures from the second semester of 2009 and the first semester of 2012, which corresponds to the period with higher number of records. Is observed a slight seasonal variation on the total water consumption, with a decrease in the summer months, most probably owing to reduced occupation due to vacations, but the hot water consumption shows, by far, the most marked pattern. The decrease in hot water consumption in the summer months results from both the decrease in total water consumption and, particularly, the shift towards using a larger proportion of cold water. In fact, Gerin et al. [17] observed a seasonal variation of the mean monthly domestic cold water temperature in the city of Brussels between 3ºC, in February, and 17.5ºC, in July and August, as well as a direct correlation between the cold water temperature and its consumption, since in summer less hot water is used compared to winter, because the temperature of the cold water is higher. In this regard, a higher proportion of cold water is needed, in relation to hot water, to reach the needed volume at the same shower temperature. This preposition assumes that individuals take shower at constant temperature, during the whole year.

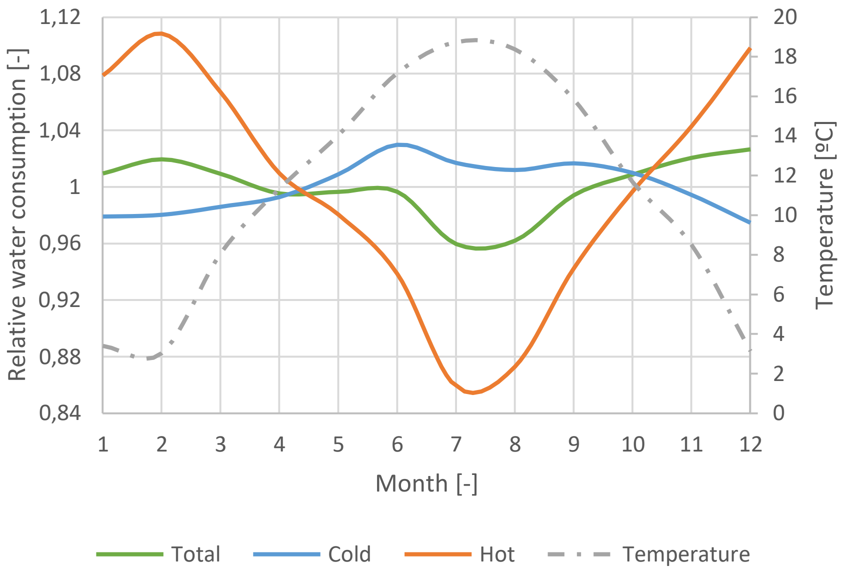

Fig. 3. Relation between relative total, hot and cold water consumption and temperature

The Pearson correlation between the temperature and the cold and hot water consumption was 0,39 and -0,88, respectively. The correlation was estimated considering the full series of average temperatures and relative cold and hot water consumption between 2008 and 2012. However, estimating the correlation for the average year represented in figure 3 results in an increase in the correlation to 0.93 and -0.97 for cold and hot water respectively.

Analysing the proportion of cold and hot water consumption (cold or hot water consumption / total water consumption) the dependence on the air temperature becomes cleared (figures 4 and 5). The absolute value of the Pearson correlation in both cases is 0,88, but for the hot water the signal is negative.

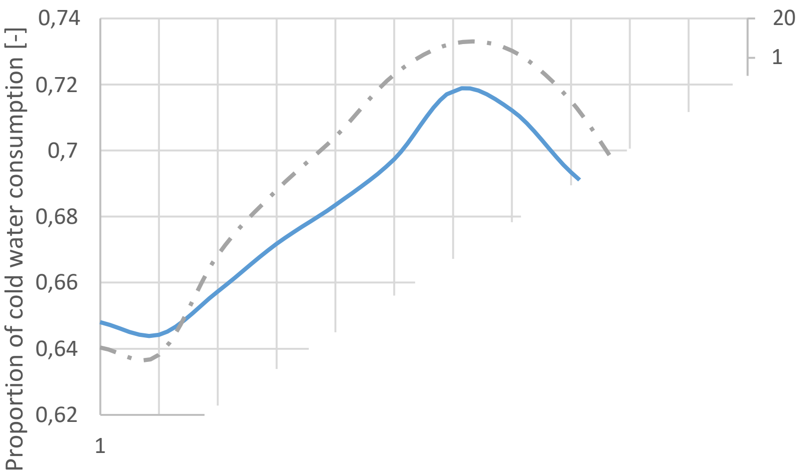

Fig. 4. Relation between cold water consumption and temperature

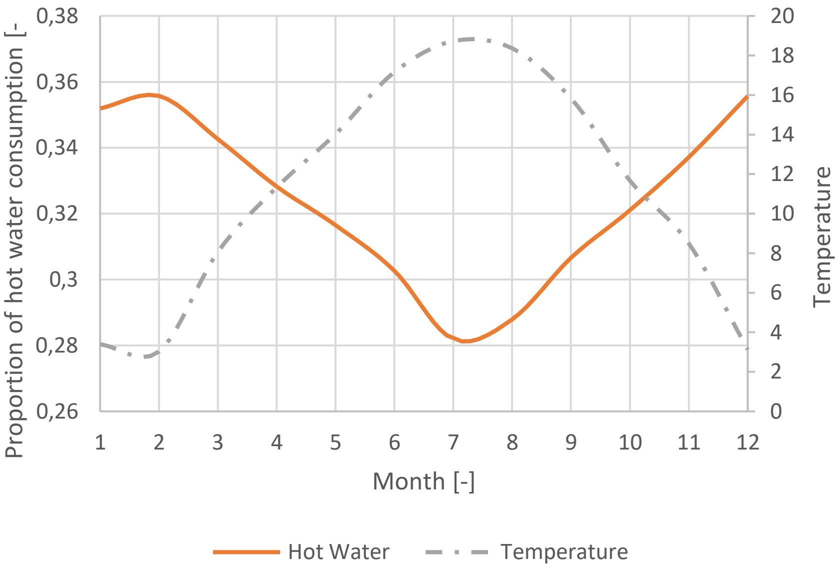

Fig. 5. Relation between hot water consumption and temperature

For the Portuguese case study, the proportion of cold and hot water consumption is observed to have higher variability than for the Belgian case study, since the data is presented on a daily basis, not being smoothed by the monthly average (figures 6 and 7). Nevertheless, the dependence on air temperature is also observed. The absolute value of the Pearson correlation in both cases is 0.70, although for the hot water the signal is negative as observed for the Belgian case study.

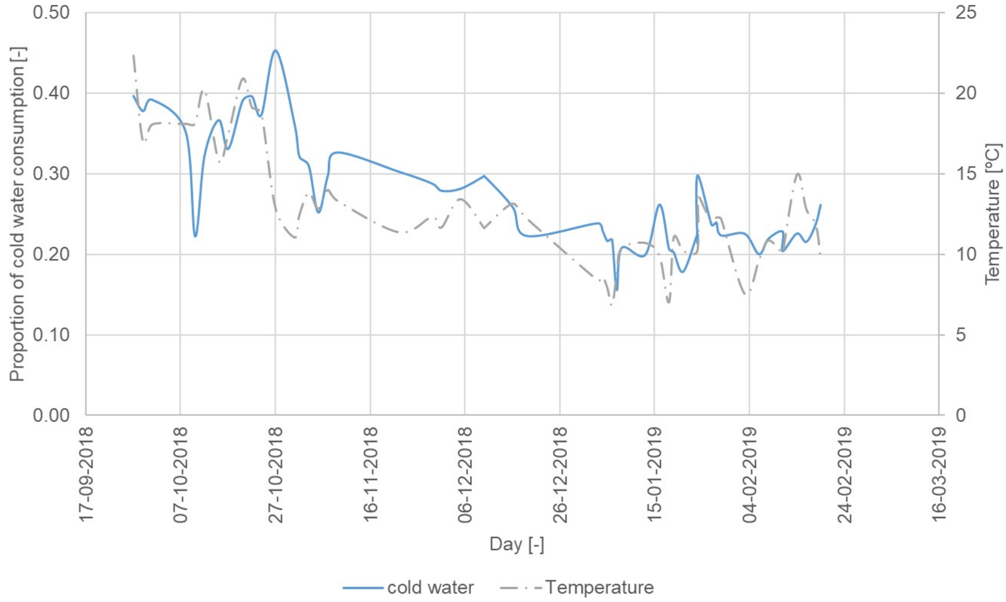

Fig. 6. Relation between cold shower water consumption and temperature

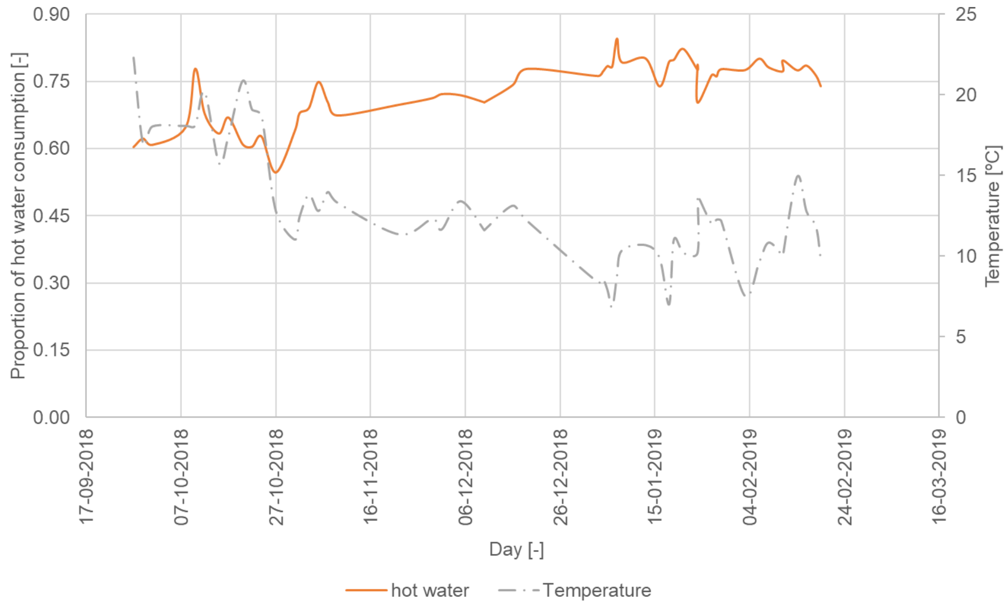

Fig. 7. Relation between hot shower water consumption and temperature

4. CONCLUSION

Domestic hot water use represents a major portion of energy consumption at residential building level. Understanding its drivers and patterns is a requirement for estimating the performance of efficiency measures, either on the amount of hot water consumption or the water heating solution, and alternative energy sources.

This study analyses data from two very distinct case studies. The Belgium case study captures the overall cold and hot water consumption pattern at a monthly time scale of a large sample of buildings. The Portuguese case study uses high resolution records of cold and hot water consumption on the bathroom of a single dwelling. Despite the stringent differences, a similar and strong correlation (Pearson correlation over 0.70) between cold and hot water consumption and air temperature is found in both cases.

As expected, the cold water consumption has a positive correlation with the temperature, while the hot water is negative. The present study provides a quantification of that relation, with an increase of 12ºC in Belgium leading to a decrease of 8% on the proportion of hot water consumption and in Portugal to a decrease of 30%. This indicates that it is not only the magnitude of temperature variation but also the range of temperatures driving the hot water consumption.

It should be noted that the apparent incompatibility in terms of scope of the case studies only applies for the cold water consumption. In Portugal, the hot water consumption is almost limited to showering and bathing. This is explained by, one hand, the warmer weather, with the public water temperatures rarely falling below 10-12ºC. This limits the need for hot water in other uses. On the other hand, water is mainly heated at the dwelling level (only a neighbourhood in Lisbon has centralized hot water production) and recirculating systems are rare. Considering that gas-fired boilers are the most common solution, the time needed for hot water to reach the point of use limits its use in many situations (e.g., hand washing).

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#3. Knowledges, engagement & participation for social change

Initiating a public conversation about community water resilience and climate adaptation through a Water Resilience Summit

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ABSTRACT

For many in the UK, the impacts of climate change will first be felt through its effects on water. A 2019 Ipsos MORI survey revealed that 85 per cent of adults in the UK are now concerned about global warming, the highest figure since 2005. It appears that people are now thinking about these potential impacts as a challenge that we will face in our lifetimes, here in the UK.

In recognition of this emerging threat and to build on the burgeoning interest in the issue of climate resilience and adaptation, a Water Resilience Summit was held in Totnes on 12th September 2019. The free and open to all event was designed as a day of action-orientated discussions, learning, knowledge exchange and collaborative planning. It brought people from all walks of life together with a broad collection of ‘resilience champions’ to explore how local water environments provide vital benefits to us all every day and to discuss what the benefits of being resilient (or the consequences of being non-resilient) might mean for people, communities, businesses and nature over the next 20 years.

Over 160 people registered to attend and over 130 people attended on the day. The programme included contributions from 30 'resilience champions' and there were many more who were unable to attend. There were also six exhibits presented during the event and over 160 questions, concerns, observations, and suggestions were contributed by the attendees. An evaluation survey revealed that the objectives of the event had largely been achieved.

Keywords: Water resilience, Community engagement, Participatory Modelling, Climate adaptation, Collaborative governance, Social capital, Co-creation, Nature Based Solutions

1. INTRODUCTION

Water is a vital resource that sustains both our natural environment and the people, communities, business, and local economy that rely on it for their survival, wellbeing and/or productivity. However, despite being our most precious life-giving resource, water resources are coming under ever greater pressure and it is now clear that there will be occasions in the future when the supply of fresh water from our environment will be unable to meet the increasing magnitude and diversity of the demands being placed upon it. As the pressure on both water supply and demand increases, water supply crises and the associated socio-economic and environmental impacts resulting from them, are now predicted to occur with ever increasing frequency and severity.

It is anticipated that, in the UK, the impacts of climate change will be initially be felt through effects on water – especially through increased flood risk and water shortage or droughts [1].

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The 2018 UK Climate Projections [2] indicate that there will be a far greater chance of hotter, drier summers and warmer, wetter winters [3]. The ‘high carbon emissions’ scenario in the UK climate projections indicates that our summers could be ~6° hotter and ~57% drier by 2070. This means that summer droughts are very likely to be both more frequent and potentially more severe [4].

In 2019, an Ipsos MORI survey revealed that 85% of adults in the UK are now ‘concerned’ about global warming, the highest figure since 2005 [5]. The proportion of people who are ‘very concerned’ about climate change has jumped to a record 52%, up from 18% five years ago. Nearly three-quarters of Britons believe the country is already feeling the effects of climate change — up from 61% in 2017, 55% in 2014 and 41% in 2010. For the first time, it appears people are thinking about the potential impacts of climate change as a challenge that we will face here in the UK, within our lifetimes.

Despite this increasing level of awareness, however, there remains very little concrete information about what the future challenges may be, and most people still have little knowledge of what the likely impacts of climate change on them and their communities will be [7, 8]. Even less is known about how resilient we as individuals and communities are to withstand these impacts the increased awareness of the issue does not appear to have inspired and empowered people to change their behaviour or take action to increase their resilience. Instead, it actually appears to have reinforced a growing sense of helplessness and what some are calling ‘climate resilience anxiety’ [6].

Further evidence of this knowledge gap has been revealed by research into the public awareness of the likely climate change impacts that will be experienced in the UK [7, 8]. This showed that, while many people are aware that climate change could increase the frequency and intensity of floods and droughts, the perception of drought risk and the potential impacts of water shortage remains especially low. Generally, there is a far higher level of concern about flooding than drought, especially following the winter floods of 2013/14. Another survey reported that, amongst those respondents reporting increased concern about climate change, only 6% referred to rising temperatures or hot/dry weather as a reason for increasing concern, compared to 26% who made reference to flooding and/or heavy rain [9]. These findings are supported by results from a 2013 Ipsos survey conducted for the Department for Environment, Food and Rural Affairs (Defra), which revealed that respondents were less concerned about increasingly frequent, severe heat waves than they were about flooding [10].

It is clear from the scientific research that our ability to balance the supply of water from the environment (rainfall being regulated and provided by our natural ecosystems) and demand/need for that water will be severely challenged over the coming decades. Our ecosystems are not hydrologically resilient, our water supply infrastructure is not working optimally, and our citizens, communities and businesses are neither using water in a sustainable way nor resilient to the impacts of water shortage. In simple terms, there is a significant risk that we are not resilient to the imminent threat we face to our water resources from population growth, pollution and a rapidly changing climate.

The scientific evidence of the threat individuals, communities and culture will face because of climate change is now clear. Even if humanity reduces its collective carbon emissions to the absolute minimum level now, the Earth’s climate will still be profoundly changed in a way that will have a significant impact on our lives living in the UK. There is clearly now an urgent need for a regenerative whole-system approach to the management of water resources that recognises the critical linkages between water, climate, energy and food production and which integrates the consideration of water into almost every policy area.

However, even if this transformative change in the way we manage water resources is successfully achieved, it is still unlikely to be sufficient to deliver a water resilient future. In addition, our society (citizens, communities, environment/nature, local economy) will also need to adapt and build its resilience to the challenges we will face over the next 10-20 years and, to achieve this, a shared understanding of the nature, scale and potential impacts of those challenges will first need to be developed. Complacency and inaction will not secure a resilient future for everyone. Reliance on a few organisations, agencies and groups to deliver a resilient future or to assume that technological solutions or the investment of financial resources will secure a resilient future will be an extremely high-risk strategy. If we are to adapt and be resilient in the future, everyone will need to change their behaviour, take action collectively and make compromises in the way they live their lives – no matter how small their apparent contribution, everyone will need to work together to build citizen, community, environmental and local economic resilience.

In recognition of the emerging threat that climate change poses to communities across the South West and to build on the burgeoning interest in the issue of climate resilience and adaptation, a Water Resilience Summit was held in Totnes on 12th September 2019. This event, which was free and open to all, was designed as a day of action-orientated discussions, learning, knowledge exchange and collaborative planning. It brought people from all walks of life together with a broad collection of 'resilience champions' to explore how local water environments (river catchments, wetlands, lakes, estuaries, coast and marine) provide vital benefits to us all every day and to discuss what the benefits of being resilient (or the consequences of being non-resilient) might mean for people, communities, businesses and nature over the next 20 years.

2. METHODOLOGY

The aim of the Water Resilience Summit was to initiate an open, honest and inclusive conversation about 'water resilience' in the South West of England. It was hoped that, by attending the event, people would be inspired and empowered to join the growing movement of people and organisations working to make the South West more resilient to the future challenges we face.

The aims of the event were for the attendees to: 1) discover how the health of the water environment affects our lives (positive and negative); 2) learn about the work being undertaken to assess how resilient the environment, people, communities and businesses of the South West are to the challenges we face now and in the future; 3) meet an array of local people and organisations (the 'resilience champions') from across the region who are already working to increase the resilience of their local environment and to learn first-hand about the challenges they are facing and the actions they are taking to overcome them, and 4) be inspired and empowered to participate in the co-design and co-delivery of a water resilient future for the South West landscape and its communities.

The expected outcomes of the event were to: 1) raise awareness of the work being done to build 'water resilience' and adapt to climate change in the South West; 2) increase the attendees level of preparedness to take practical action to build 'water resilience' or change their behaviours to adapt their lifestyle to climate change impacts, and 3) provide reassurance to people (reduce their anxiety) by showcasing the significant efforts of people and organisations already being undertaken to build 'water resilience' and mitigate the impacts of climate change on the water environments and communities of the South West.

2.1 Target Audience

The Water Resilience Summit was promoted widely as a public event with the intention that the attendees would represent a diverse array of stakeholders that included citizens, local businesses, community representatives, civil society groups and professionals from across the South West region.

At the outset, a detailed analysis and segmentation of all potential audiences was undertaken that included a comprehensive review of the different socio-economic groups, cultural backgrounds, religions, genders, age groups, etc in the South West target area. A detailed characterisation of the different categories of citizens, civil society groups and communities (geographic and 'of interest') in the region was also undertaken and the potential of each to benefit from an initiative of this nature was characterised.

A Theory of Change [11] was also developed for the event and the wider communication and engagement campaign to examine how it could deliver significant social, cultural and (in the longer-term) environmental benefits for people of all different socio-economic groups, cultural backgrounds, religions, genders, age groups, etc. Raising awareness of and changing people's attitudes towards environmental hazards and the measures that can effectively be taken to mitigate them, have been shown to be vital first steps in building resilience – by empowering behaviour change and motivating people/communities to (collectively or individually) take action in their local environment.

Ultimately, anyone who had worries, concerns or questions about the issue of water resilience (and climate resilience in general) were encouraged to attend.

2.2 Design of the Summit - Programme

It was intended for the event to provide an open forum for the exchange of knowledge, information and contact details and for the provision of emotional and practical inspiration, guidance and support.

The structure of the event is shown in Figure 1. The opening session was a series of 'provocations' to set the scene and lay down the challenges the event was designed to address and the actions that would follow. In each subsequent section of the programme, speaker contributions were 'curated' and sequenced to develop a clear narrative about each of the broad landscape types across the South West. After each section, of the programme, the attendees were invited to add any questions, concerns, thoughts or sentiments to a 'wall' of questions and answers. Participants were invited to scrutinise these contributions during the day and, were possible, provide answers or responses (either during or after the event).

2.3 Speakers – the 'Resilience Champions'

Contributors (the 'resilience champions') were recruited from across the South West (and further afield) and from a wide array of backgrounds. They were challenged to give a short 'keynote'-style talk or speech about one aspect of the subject. The aim was for each speaker to give an honest appraisal of the situation as they understand it (including being prepared to openly admit that they 'don't know'). Each speaker was asked to focus on one element or aspect of the issue and to speak in general terms about why that element is important for water resilience, whether they consider it be resilient now, what the consequences of it not being resilient might be, and to set out a vision for what it will need to be like in the future if it is to withstand the challenges that lie ahead.

Speakers were given clear instructions that the aim of the event was to reassure the attendees, but not to placate them or fob them off with platitudes. A climate emergency has been declared, but it was vital that their contributions did not reinforce any anxieties nor perpetuate any perception that nothing is being done in response to the emergency. The aim was to give people hope, answer their questions and offer pragmatic, practical advice on what can be done and, perhaps most importantly, what they can do to contribute.

Most importantly, speakers were encouraged to highlight what steps they and others are taking or will need to take if their resilient future vision is to become a reality (this could include research, practical action, behaviour change, economic transformation, energy transition, regenerative land management, policy change, etc). In this way, it was hoped that the event would become a 'call to arms' that established a new collaborative approach to establishing water resilient communities.

In preparing their contributions, the speakers were reminded that, because a significant number of the attendees at the event were to be members of the public, they would also be required to adjust the style and language of their contributions to suit the prior knowledge and needs of these attendees. In line with this, attendees were informed that any overly technical or confusing material or statements presented during the proceedings should be challenged as it goes directly against the stated aims of this event.

Figure 1. *The Programme for the Water Resilience Summit, Totnes, September 2019.*

3. RESULTS AND DISCUSSION

Over 160 people registered to attend the Water Resilience Summit in Totnes in September 2019 and over 130 people attended on the day (including several people who joined after seeing promotional material and hearing media coverage on the day).

The final programme included contributions from 30 'resilience champions' who presented on the day and there were many more who were unable to attend. There were also six exhibits presented in the venue on the day, which received a great deal of attention from the attendees.

Figure 2. *Photos from the Water Resilience Summit, Totnes, September 2019.*

As stated previously, the attendees were invited to add any questions, concerns, thoughts or sentiments to a ‘wall’ of questions and answers. Participants were invited to scrutinise these contributions during the day and, were possible, provide answers or responses (either during or after the event). By the end of the Summit the wall had received over 160 questions, concerns, observations and suggestions. These were supplemented by numerous messages giving feedback and making further enquiries in the immediate aftermath of the event.

The contributions from the attendees were reviewed and analysed by the project team, supported by Jane Brady from the South Devon Bioregional Learning Centre and Lee Eyre, an associate of the BLC. A simple thematic assessment of these contributions revealed 7 broad questions that people wanted to receive answers to:

1. What does water resilience mean?
2. Why is water resilience important?
3. How do you measure (progress towards) water resilience?
4. How much water resilience do we have now and how much do we need?
5. What are the biggest threats to water resilience?
6. Whose responsibility is water resilience?
7. How / what actions can we take to increase water resilience?

In addition to these top-level questions, there were also several additional sub-themes that emerged that could be used to refine the top-level questions and provide a framework for more in-depth assessment. These included a focus on these questions in relation to human/community health and wellbeing, socio-cultural factors, ecological/ecosystem health and function, the roles and responsibilities of organisations such as the Environment Agency and Water Companies.

The information generated through this exercise was used to inform the design and delivery of the follow-up actions undertaken since the event. These include the development of a **water resilience presentation** that has been given to community groups across the region, the **Community Water Resilience Hub and Library**, the **Community Water Resilience Fund** and the **WaterTight – Water Resilient Communities Campaign**, which is now being piloted as a Living Laboratory action-learning project in South Devon. These initiatives are summarised in the Conclusion and Next Steps section.

To gauge how successful the Summit was in realising its three main objectives, we performed a simple evaluation exercise during the event. Attendees were invited to answer three questions using a visual analogue scale upon their arrival at the event and then their responses to the same three questions were elicited again at the end prior to their departure.

The results of this evaluation (shown in Figure 3) indicate that the overall awareness of the work being done to build 'water resilience' and adapt to climate change in the South West was significantly increased and that the attendees reported level of preparedness to take practical action to build 'water resilience' or change their behaviours to adapt their lifestyle to climate change impacts was also increased.

Interestingly, while the event did provide reassurance to some of the attendees (who reported that their anxiety levels had reduced), there were also a number of attendees who reported that their anxiety levels had increased (perhaps in line with their increased level of awareness of the challenges we face). This resulted in no overall change in the level of anxiety reported.

It is important to note that there are some potential negative impacts of raising awareness of issues such as flooding or drought risk – especially in relation to anticipated climate change impacts [12]. These mainly relate to the very real health and wellbeing impacts that can occur when people knowingly live at risk of flooding (mainly triggered through the generation of fear/anxiety). This potential negative impact was mitigated through the careful design and implementation of the messages and language used during and after the event. In this way, it was hoped to ensure that the net outcome of this engagement and communication was a positive outcome for the participants and that awareness raising did represent a critical first step towards building individual and community resilience.

Figure 3. *Results of the monitoring and evaluation survey undertaken at the Water Resilience Summit.*

4. CONCLUSION AND NEXT STEPS

Following the successful delivery of the Water Resilience Summit, a series of interventions have been initiated to build on the lessons learnt and the outcomes achieved though the event. This programme of activities has been integrated and funded under the banner of the newly established **WaterTight – Water Resilient Communities Initiative**.

The aim of this initiative, which is being delivered by a coalition of organisations in the South West and led by Westcountry Rivers Trust, is to grow individual and community interest in ways to adapt to water resource pressures and implement best water-use practices, while also offering the opportunity, via support and advice, to learn coping strategies to alleviate any anxiety felt in the face of climate change challenges.

The initiative currently has 4 main stands of activity: 1) the development of a **water resilience presentation/webinar** that has been given to community groups across the region; 2) the design and creation of a **Community Water Resilience Hub and Library**; 3) the establishment of the **Water Resilient Communities Fund**, and 4) the initiation of the **WaterTight – Water Resilient Communities Campaign**, which is now being piloted as a Living Laboratory action-learning project in South Devon.

4.1 Water resilience presentation/webinar

The Water Resilience Summit was summarised and disseminated via an online report (https://sway.office.com/2aaS8GY4SA0yAgVW) and, in addition, a presentation was developed to continue the communication and dissemination of water resilience to a wider audience following the event [13]. This presentation was given at a meeting of the **Devon Community Resilience Forum** and subsequently at several follow-up events where it generated significant interest and useful connections to other practitioners and stakeholders.

4.2 Community Water Resilience Hub and Library

Taking inspiration from the Northern Manhattan Climate Action Plan [14], for which they have co-designed a 'community kiosk' that will serve as an information hub about climate change called the +SPACE Manhattanville Community Hub [15], a Community Water Resilience Hub has been constructed. This takes the form of a geodesic dome and will be used to take the conversation about climate change adaptation, water resilience and community resilience out into local neighbourhoods across the South West over the coming months and years.

The Hub was launched officially at the Water Resilience Summit and several requests were received for it to be used in communities seeking to start a conversation about climate resilience and adaptation (delayed by the COVID-19 crisis).

The Hub's tour of the region is to be supported with funding from Westcountry Rivers Trust projects, such as PROWATER, Sponge 2020 and Plymouth River Keepers, but the plan is for it to be financially supported by the newly created Community Water Resilience Fund which will be used to support the ongoing community engagement approach initiated after the Summit.

The Hub has also been designed to house the Watertight Community Water Resilience Library (which is also being launched as a virtual online resource following the COVID-19 crisis). The aim is for the Hub and Library to be a welcoming space where people can find information, strike up conversations, meet other members of their community and receive support relating to climate change pressures particularly in relation to water resources issues. The space will be kitted out with books, leaflets, and 'furniture' to create the ambience of a private library. The library will be use at a wide array of Westcountry Rivers Trust-hosted and external public events.

4.3 Water Resilient Communities Fund

The **Community Water Resilience Fund** has been established to initiate and facilitate an ongoing open, honest and inclusive conversation about water resilience in the South West. The Fund will help create a forum for the exchange of information and for the provision of emotional and practical inspiration, guidance, support, etc. It will also support the further development and deployment of the **Community Water Resilience Hub** in communities across the region.

Fundraising began at the Water Resilience Summit and has continued via a number of activities since. The fund has also received some donations from other aligned Westcountry Rivers Trust projects, which are co-financing the WaterTight campaign.

4.4 WaterTight – Water Resilient Communities Project

The newly initiated **WaterTight Water Resilient Communities Project** has been designed to build on the outcomes achieved during the Water Resilience Summit. It is a place-based water resilience and climate adaptation initiative that aims to build socio-economic and environmental resilience in local communities via a collaborative 'water stewardship' approach.

The aim of the project is to establish the first truly water resilient (or WaterTight) communities in the UK in the South West. To achieve this, a place-based **Water Resilient Communities Living Laboratory** (**WRCLL**) is to be established. Living Labs are user-centered open innovation research platforms based on a systematic user-focused co-creation approach that integrates action research and innovation into real life communities and settings [16].

The WRCLL will be based on 3 'building blocks' of community water resilience and adaptation: 1) creating social capital; 2) facilitating stakeholder learning/understanding, and 3) restoring ecosystem health and function by co-creating of nature-based solutions. The WRCLL will work to study, understand and optimise the supply (natural water cycle) and demand (human water cycle) sides of the local water system.

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FURTHER INFORMATION

Water Resilience Summit Report - https://sway.office.com/2aaS8GY4SA0yAgVW

PROWATER website – https://www.pro-water.eu/

Westcountry Rivers Trust WaterTight webpage - https://wrt.org.uk/project/be-watertight/

Bioregional Learning Centre website - https://bioregion.org.uk/

COMPETING INTERESTS

The authors declare there are no conflicts of interest or competing interests. The funders were not involved in the project design, data collection, evaluation or writing of the manuscript.

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SPONGE2020 Local Action Project: Using nature-based solutions to reduce surface water flooding and deliver multiple benefits

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ABSTRACT

Managing the rainwater that falls on our towns and cities is an important task. As we start to feel the effects of climate change, extreme rainfall events are expected to increase. This is creating real challenges for water managers and local authorities. SPONGE 2020, an Interreg 2 Seas project, part-funded by the European Regional Development Fund, has been working with local stakeholders for 3 years to co-create innovative adaptation measures across a range of settings to reduce the impact of climate change and make communities more resilient.

Keeping water at the surface and allowing it to slowly soak into the ground or drain away over a longer time-period eases pressure on the drainage system and reduces the risk of water pollution and flooding. Sustainable Drainage Systems (SuDS), like raingardens, ponds and planters, slow the flow of water, are great for wildlife and are an interesting and attractive addition to homes, gardens, streets and local spaces. By creating lots of these features, all over our towns and cities, we can reduce the risk of flooding, clean up local streams, make more space for wildlife, and create smart green places for everyone to enjoy.

Through SPONGE 2020, Westcountry Rivers Trust and Somerset County Council have worked with a wide array of communities in Somerset towns to install SuDS features and encourage people to make changes to their water resilience in their own homes and activities.

Keywords: Water resilience, Community engagement, Participatory Modelling, Climate adaptation, Co-creation, Nature Based Solutions, Natural Capital, Urban Ecosystem Services

1. INTRODUCTION

Managing the rainwater that falls on our towns and cities is an important task. As we start to feel the effects of climate change, extreme rainfall events are expected to increase. Paved surfaces in urban landscapes cause water to rush into our sewers and rivers and this, in turn, increases flood risk, causes sewers to be overwhelmed and together this mobilises pollution into rivers and streams [1].

The traditional ways of managing our rainwater have advantages and disadvantages, but increasingly they are causing problems when there is heavy rain as they are not designed to regulate the flow of the volumes of water generated in a short period of time. This lack of resilience in our water management infrastructure is creating significant challenges for water

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managers and local authorities.

SPONGE2020 is an Interreg 2 Seas (www.interreg2seas.eu) project, part-funded by the European Regional Development Fund. This European program aims to increase international collaboration in tackling challenges that cross over international borders – for example, dealing with the consequences of climate change.

The Somerset Pilot for SPONGE2020, which is being delivered by Westcountry Rivers Trust working in partnership with Somerset County Council between 2018 and 2021, has the objective of implementing targeted interventions to prevent surface water flooding and improve the urban landscape that have been co-designed and co-created with local communities. The focus of the project is on the targeting, design and delivery of nature-based solutions (NBS) [2] and sustainable drainage solutions (SuDS) [3] for climate change resilience in partnership with local communities and local authorities. These objectives of SPONGE2020 provided and excellent opportunity to road-test the methodology and tools previously developed as part of the Defra-funded Local Action Project in a real-life community-based situation.

The Defra-funded Local Action Project (LAP), was undertaken by the Westcountry Rivers Trust, Defra Network Organisations and researchers from Imperial College, London, in partnership with a variety of local practitioners and stakeholders in four demonstration areas (including Manchester, Leicester, London and Devon) [4,5].

LAP provided research and development outputs that presents robust data, evidence and information on the benefits of green infrastructure and natural capital along with a method that helps communities build consensus, facilitate local decision-making and secure funding for natural capital improvements.

The LAP approach and ethos was specifically designed to help meet the objectives set out in the Government's recently published 25-Year Environment Plan (25-YEP) [6]. At its core, the 25-YEP is based on several key challenges that will require environmental practitioners and policy-makers to: 1) consider the value of nature in decision-making; 2) develop innovative tools and finance methods that use the latest science, data and technology; 3) plan and deliver action at the most effective scale and in a collaborative, inclusive and integrated way that breaks down silos; and 4) re-connect stakeholders with their local the environment and empower them to take action to protect and enhance it.

The main output of LAP was a framework for the assessment and targeting of nature-based solutions that could then be co-created, refined and tailored through consultation with local stakeholders and with locally-specific data and evidence. This approach leads to the creation of a shared resource that becomes a powerful enabler for people attempting to deliver local actions in the urban environment.

A key success criteria for the project was therefore the demonstration that the resources/approach developed can be up-scaled and/or transferred to new locations across the country at a variety of spatial scales – hence why SPONGE2020 represented an excellent 'living laboratory' in which to test and study the approach.

In this case study, we summarise the work undertaken to target, co-design and co-create nature-based solutions (also known as ecosystem-based adaptation measures) in the urban landscapes of Somerset integrating the LAP and SPONGE2020 methodologies. We have demonstrated that this approach can be highly effective for the delivery of these multi-beneficial interventions and to build both social and natural capital in the targeted landscapes.

2. METHODOLOGY

2.1 Strategic Data and Evidence

Numerous studies [e.g.7, 8, 9] have now shown that undertaking a stakeholder-led participatory systematic review of data and evidence relating to a catchment landscape, when facilitated by an impartial 'knowledge broker', can help to achieve a number of critical outcomes in the catchment planning process. For SPONGE2020, it was essential that the collaborative, 'co-creation' approach adopted for this project was underpinned by high-resolution strategic evidence collated and analysed according to the LAP methodology to inform and facilitate every stage of the process.

The LAP participatory data and evidence review process is comprised of several key stages: 1) landscape-scale assessment of need/opportunity for NBS to deliver benefits; 2) characterisation of high-priority and multi-opportunity target areas for NBS delivery; 3) identification of specific candidate NBS delivery sites; 4) conceptual NBS (SuDS) intervention design and optioneering/co-design with stakeholders, and 5) estimation and/or measurement of ecosystem service benefits realised.

2.1.1 Socio-economic priorities and drivers

Before assessing the baseline of benefits received by local communities, it is important to consider any existing priority areas and drivers for improving natural infrastructure, including legislative drivers and restrictions, socioeconomic patterns, funding incentives or local plans. Where these social drivers are present, they can represent both an enabler and motivator for action to deliver 'nature-based solutions' into these areas and also a potentially significant blocker to environmental action (as these issues often take priority).

There are numerous priorities and drivers that affect the management of natural resources in an urban area. Two reviewed in Taunton were social deprivation and health. It is well-documented that areas of social deprivation are often linked to poorer health, reduced air quality, increased crime rates and lower access to natural spaces. Many types of natural interventions provide benefits that address some of these issues. It is important to assess which parts of the city are suffering from socioeconomic problems and to investigate whether natural infrastructure could contribute to resolving them. These factors should be kept in mind throughout the strategic targeting process [4].

2.1.1 Current natural capital and ecosystem services provisions assessment

During LAP1 a simple, but rigorously developed, framework was developed for the assessment of natural capital- and ecosystem services-derived benefits in urban landscapes [4].

The assessment method characterises a series of 12 indicators, visualised in a wheel graphic, which can be used to establish a baseline of the net-benefits experienced by people living in a specific or across a number of communities (facilitating a strategic assessment of the 'need for enhancement' or the deficiency of provision).

Once created, the wheels become a powerful 'knowledge-brokerage' or decision-support tool that can facilitate a strategic and collaborative spatial prioritisation of 'need' for the protection, improvement or creation of natural capital assets - i.e. they help build a mandate for action and target that action into the areas of greatest potential benefit. By giving stakeholders (citizens, civil society and professional) an engaging and highly visual multi-parameter assessment of need/opportunity for action, the Wheels stimulate an informed discussion among local stakeholders, practitioners and decision-makers. This in turn helps build consensus/ambition, develop a shared vision and expedite a more robust and informed decision-making process at a local scale.

In Taunton, the LAP wheels were customised to account for the most relevant priorities for the town. To achieve this, the previous work already undertaken for LAP was built upon through a series of workshops/meetings with practitioners, other professional stakeholders and policy-makers. In these workshops, the stakeholders worked to scrutinise the indicators developed for the original wheel and, where they considered it appropriate, change either the metrics, the data used to calculate them or the methods used to analyse them for the town.

When developing an approach of this type, it is vitally important that robust, spatially consistent and well characterised datasets are used to inform the wheel scores. In the SPONGE2020 analysis for Taunton, we have utilised the latest most up-to-date information and data to ensure reliability, accuracy and consistency of each indicator score.

In Somerset target landscape under study, initially Taunton, the Super Outputs Areas (SOAs) were each ranked for each of the 12 indicators or metrics. This enables the ‘Net-Benefit Wheels’ to be created and mapped to give a strategic overview of the ecosystem services or natural capital ‘needs’ of the people living in each community.

2.2 NBS/SuDS Toolbox of Interventions

Another output of the Local Action Project was the urban NBS intervention toolbox [4]. This catalogue of interventions was compiled by reviewing existing typologies of green infrastructure components and sustainable drainage systems. To allow comparability and consistency throughout the use of the output from the Local Action Project, and to make the use of the toolbox as simple as possible, the same twelve indicators for benefits were used to describe interventions as for the GIS based net-benefits needs assessment.

The key natural asset typologies and interventions to be restored/delivered during SPONGE2020 were selected from the LAP Interventions Toolbox and adapted for use during the co-design and co-creation process undertaken in Taunton.

2.3 Stakeholder engagement and co-design/creation

Once target locations and potential sites have been identified, we will use a variety of communications channels/methods to engage community groups and residents in these locations and inform them of the upcoming opportunity to collaborate in the project.

Following this initial engagement, a series of workshops/discussion groups were convened with all of the key stakeholder groups identified to: 1) raise awareness of challenges faced in managing water in urban areas and 2) explore opportunities for them to contribute to the process of creating community-based NBS/SuDS. The messages and language used in this stakeholder engagement process were aligned with the audience’s prior knowledge and tailored to focus not only on issues such as flooding and water quality, but also on place-making, creating resilient communities, and the health and wellbeing value of SuDS and green infrastructure in urban communities.

Having worked with local residents to develop a shared understanding of the potential benefits of NBS/SuDS (what were referred to as raingardens during the project) and to inspire ambition for the future of their community’s landscape, we then worked with them to co-design the interventions to be delivered in their properties/community spaces – encouraging them to take a leading role in tailoring the design of adaptation measures to best suit the situation at each site. Critical elements of the SPONGE 2020 approach have been the engagement of local stakeholders and their participation in the design and creation of the NBS/SuDS, helping people understand how surface water flooding affects them and how it is affecting others, and inspiring and empowering citizens to take action to increase the resilience of their town or neighborhood.

2.4 Monitoring and Evaluation

For co-creation approaches to be demonstrably effective in delivering additional benefits (and for their full potential impact to be realised), there is a vital need for their implementation to be underpinned by a robust monitoring and evaluation (M&E) methodology. This allows practitioners to comprehensively assess and report the delivery of both the outputs delivered by the project (activities undertaken) and the successful realisation of its intended outcomes (the environmental, social, cultural and economic benefits realised).

During the Defra Local Action Project [4] and the SPONGE2020 Project, WRT have worked with Somerset County Council and other partners from across the UK and the Interreg 2-Seas Area, to develop one of the first **Co-Creation M&E Frameworks** ever designed for the assessment of community-based NBS, SuDS and GI initiatives in the UK (and Europe). The M&E framework was based on a Logical Framework (logic-model) Approach [11]. Logframes can be very effective tools to help describe the relationship between an intervention’s inputs, activities, outputs, outcomes, and impacts [11]. They can also be especially effective when integrated with a ‘Theory of Change’ – ToC [11]. The UK Government Magenta Book considers logframes to be among the best methods for evaluating policies and interventions [12].

The SPONGE2020 M&E ‘toolkit’ was designed to assess and demonstrate:

1) Robust design and implementation of co-creation activities or outputs (supported through use of various stakeholder engagement and co-creation toolboxes),
2) Successful realisation of the intended outcomes of the co-creation technique applied (e.g. changing stakeholder awareness/knowledge, initiating behaviour-change, voluntary action),
3) Magnitude and diversity of the natural capital/environmental benefits generated through the collaborative delivery/co-creation of nature-based solutions,
4) Magnitude and diversity of the additional benefits generated through the effective implementation of co-creation itself (e.g. additional environmental resilience, socio-economic or cultural benefits).

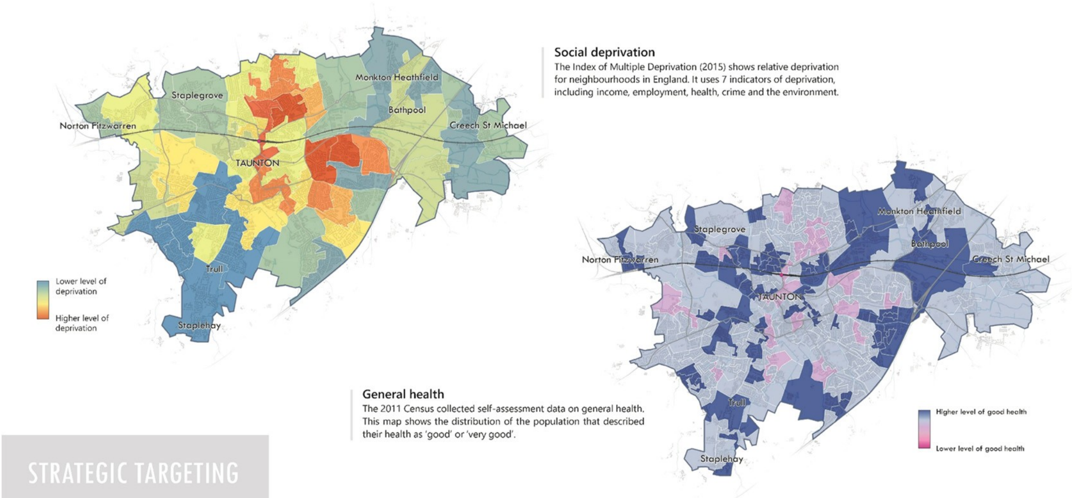
3. RESULTS

3.1 Strategic Data and Evidence

3.1.1 Socio-economic priorities and drivers

Before assessing the baseline of benefits received by local communities, it is important to consider any existing priority areas and drivers for improving natural infrastructure, including legislative drivers and restrictions, socioeconomic patterns, funding incentives or local plans. There are numerous priorities and drivers that affect the management of natural resources in an urban area. The maps in Figure 1 highlight two of these for Taunton; social deprivation and health.

Figure 1. *Stakeholder engagement and co-creation framework for SPONGE2020.*



The Taunton Deane Green Infrastructure Opportunities document is also highlighted as an existing strategy being implemented across Taunton. It is well-documented that areas of social deprivation are often linked to poorer health, reduced air quality, increased crime rates and lower access to natural spaces. Many types of natural interventions provide benefits that address some of these issues. It is important to assess which parts of the city are suffering from socioeconomic problems and to investigate whether natural infrastructure could contribute to resolving them. These factors should be kept in mind throughout the strategic targeting process.

3.1.1 Current natural capital and ecosystem services provisions assessment

The next stage of the process was to perform a comprehensive audit of the environmental infrastructure (natural capital in the landscape) and to characterise the ecosystem services these assets currently provide. This review allows assets providing important benefits to be identified and provides evidence in support of efforts to protect and enhance them. In addition, it is vital to characterise the current natural capital in the landscape to ensure that any proposed programme of interventions designed to enhance provision is strategic and correctly targeted. Full details of all datasets and analysis techniques used in this study are recorded in the SPONGE2020 Project review document [13].

The level of provision of each indicator of net-benefit or need in the LAP Wheel of metrics were then assessed and mapped individually, to characterise how each area is performing against each benefit metric. Each of the 12 metrics were assessed in detail for each of the areas and neighbourhoods of Taunton and the results are shown in Figure 2. The final summary map showing all the wheels together is shown in Figure 3.

Figure 2. *Mapped metric scores for Super Output Areas across Taunton.*

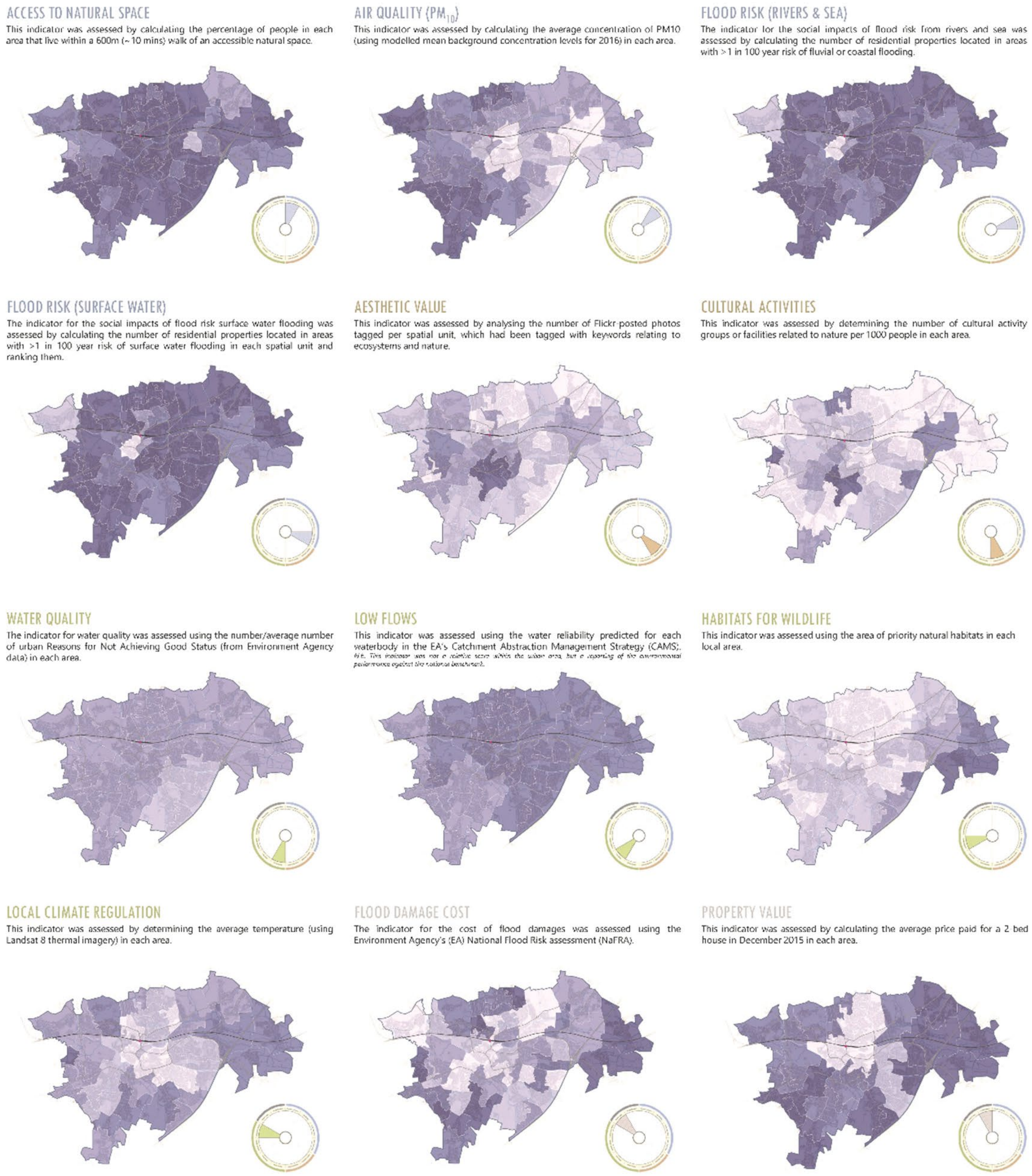
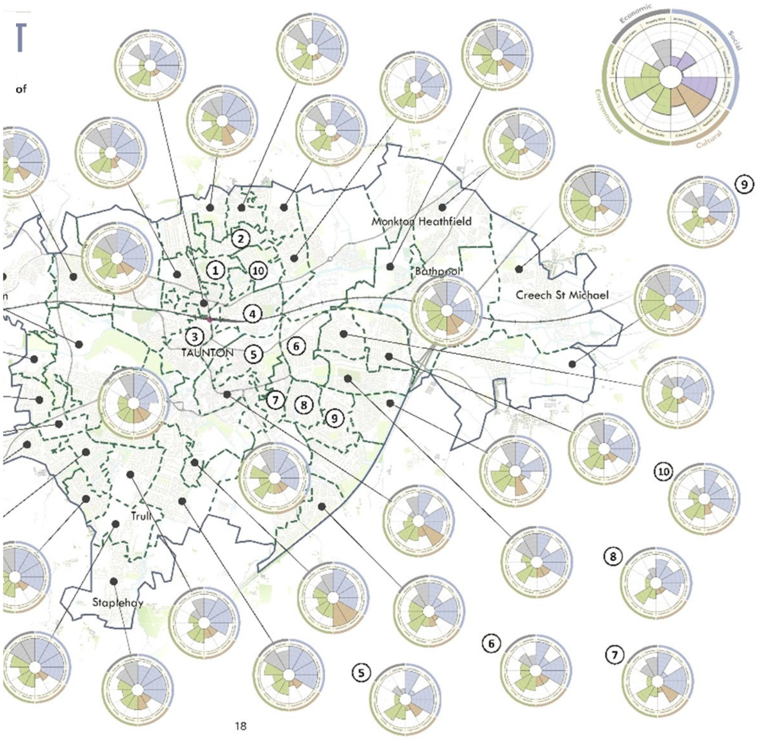
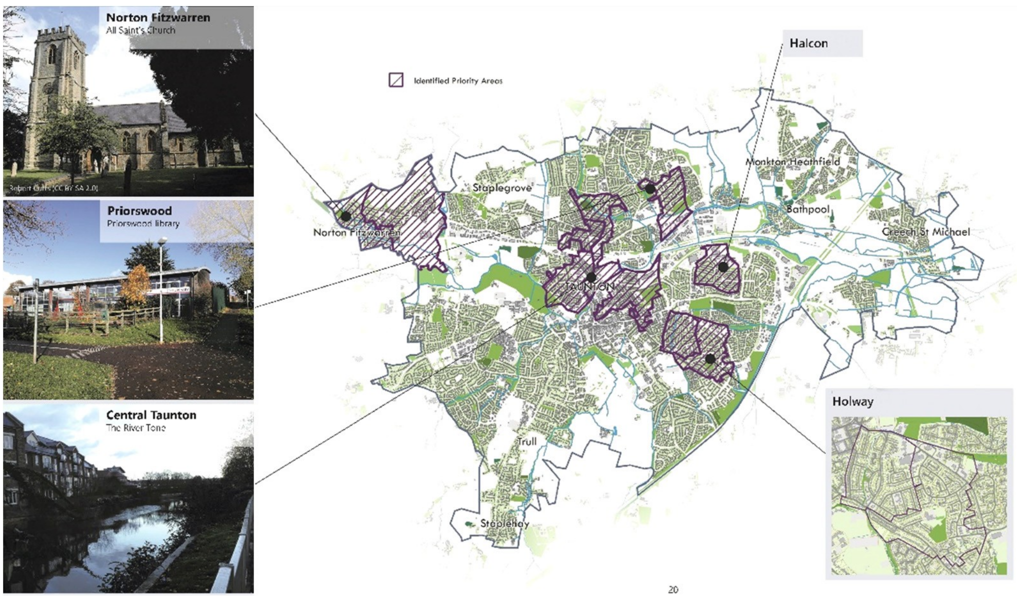


Figure 3. *Section of LAP wheels summary map for Taunton.*



Using all the data and evidence examined through this process, including issues such as deprivation, health, and the benefit-indicator metrics, several areas of Taunton were then selected as target areas for the SPONGE2020 Project. These areas are shown in Figure 4.

Figure 4. *SPONGE2020 Priority areas selected for Taunton.*



3.2 NBS/SuDS Toolbox of Interventions

The key natural asset typologies and interventions to be restored/delivered during SPONGE2020 were selected from the LAP Toolbox and adapted for use during the co-design and co-creation process undertaken in Taunton.

3.3 Stakeholder engagement and co-design/creation

Following the completion of the data and evidence and stakeholder engagement planning stages of the project, the Somerset Pilot for SPONGE2020 then entered its delivery phase, and, with co-finance provided by Wessex Water, Somerset Rivers Authority, Postcode Local Trust, the Royal Academy of Engineers and Garfield Western Trust, the team has now been working with local communities for over 2 years to design and install sustainable drainage features (raingardens), which will have a lasting impact on local spaces and communities across Taunton.

The following section presents two example case studies from this work.

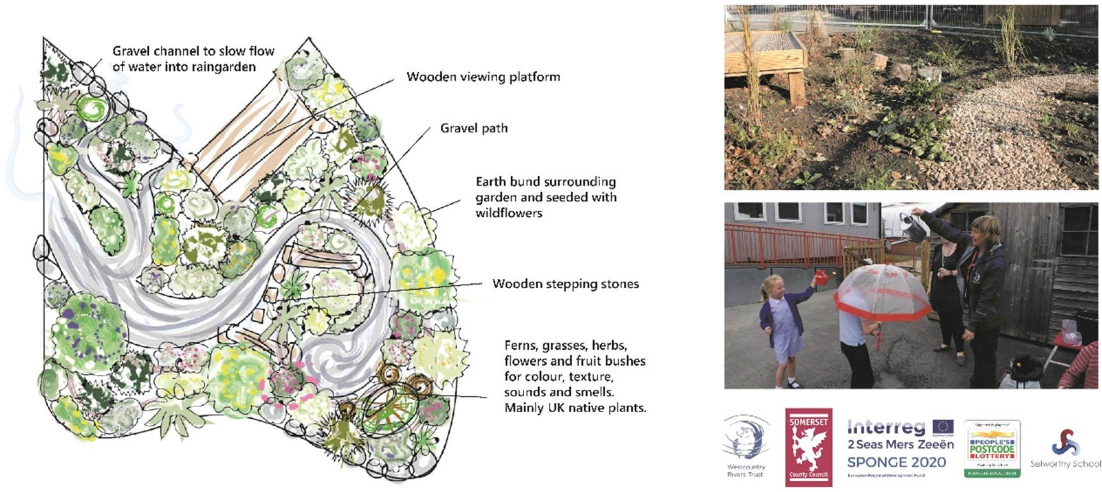
3.3.1 Selworthy School Sensory Raingarden

A sensory raingarden was co-created with parents, staff and learners at Selworthy Special School in Taunton (see Figure 5). Selworthy is a school for children and young people with learning disabilities aged 4-19.

The school uses outdoor spaces to allow their pupils to learn in the environment that suits them best. However, flooding due to a blocked surface drain sometimes left the grounds too muddy to be used. The raingarden was designed to capture the water creating this issue, removing the need for traditional drainage.

As well as reducing flooding by storing $10m^3$ of water, the garden incorporates sensory and interactive elements to enhance the space for children and staff. Children, parents and staff were involved in designing as well as planting the raingarden. In addition, workshops and interactive lessons were used to educate and engage those taking part in issues around flooding and climate change.

Figure 5. *Co-design and co-delivery of Selworthy School Sensory Raingarden.*



3.3.3 Middleway Community Raingarden

Following on from the Demonstration Raingardens Project, a second phase of work was initiated at Middleway in Taunton to build a sunken raingarden to take the rainwater from the roof of one of the buildings and allow it to soak into the ground (see Figure 6).

The raingarden was constructed in May 2019 with a planting day held as a final community event. The raingarden receives water from a roof area of approximately $70m^2$. The raingarden itself will be approximately $19m^2$, with the size estimated based on the roof catchment area, estimated rain levels for Somerset (with additional contingency to factor increase in rain in future years), and the infiltration rate of the soil. The water will be taken from the downpipe along a paved channel where it will then open into a raingarden where the water can pool during heavy rain and then soak into the ground over time. This will prevent the rainwater from going directly to the sewer, reducing pressure on the water management system.

Westcountry Rivers Trust held several meetings with Middleway residents, initially through the Demonstration Raingardens Project, and then again through a project funded by the People's Postcode Lottery. These engagement events helped with site selection and raingarden design.

Once the raingarden had been built in May 2019, there were further events to plant-up the raingarden. The garden was planted with a with a variety of plant species, with more water-loving plants in the centre where pools of rainwater will form, and grasses and wildflowers to attract wildlife and create an attractive garden. A bench and stepping-stones were added to allow residents to interact with and enjoy the raingarden.

Figure 6. *Co-design and co-delivery of Middleway Community Raingarden.*

5. CONCLUSION

Through SPONGE 2020, Westcountry Rivers Trust and Somerset County Council have worked with a wide array of communities in Somerset towns to co-design and co-create NBS/SuDS features and encourage people to make changes to their water resilience in their own homes and activities.

The SPONGE2020 Project in Somerset has provided and excellent opportunity to road-test the methodology and tools previously developed as part of the Defra-funded Local Action Project in a real-life community-based situation.

By integrating the Defra Local Action Project and the SPONGE2020 approaches, we have successfully developed and tested one of the first Co-Creation M&E Frameworks ever designed for the assessment of community-based NBS, SuDS and GI initiatives in the UK (and Europe).

ACKNOWLEDGEMENTS

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FURTHER INFORMATION

Somerset SPONGE2020 website - http://somerset-sponge.org/. Many of the outputs from SPONGE2020 can be found at https://www.urbangreenbluegrids.com/sponge/

COMPETING INTERESTS

The authors declare there are no conflicts of interest.

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The Benefits of Socio-legal Approaches to Water Research: "What do you think?"

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ABSTRACT

This extended abstract will present two legal research projects and contrast the methodologies adopted, identifying the benefits for water resilience researchers of adopting a socio-legal approach. In a consideration of the existence of a right to be protected from flooding in English law, a traditional doctrinal approach was adopted, studying the law as a closed and distinct subject. It is suggested that this approach can be a vital first step in analysing any legal problem, but that it has limited scope to help address the problems faced in water resilience. By contrast, a case study on how the public right to fish (a right of the public to harvest resources from within tidal, coastal and marine waters) is experienced and understood by those involved in fishing adopted a socio-legal methodology. This approach starts from an understanding of the law as a social institution. The focus was on how the right worked in practice and how it could be framed and used as a tool to aid marine conservation, rather than as a licence to overfish. For water resilience researchers the benefits of embracing a socio-legal approach to research can be two-fold. It can open up consideration of legal problems to a wider base of researchers and audience, and it also allows a recognition of the important role that law plays in shaping society, both in general and in how we think about and use water, within a context that allows for consideration of how society shapes law and its application.

Keywords: Socio-legal research, methodology, social-ecological resilience

1. INTRODUCTION

Law is increasingly recognised as playing a crucial role in the fostering of resilience in social-ecological systems [1] [2]. This role is described in a multitude of ways, many of which recognise the potential for negative impact in the functioning of the law in connection to such systems. For example, Ebbesson and Hey neatly summarise the role of law and its constituent parts (its institutions, structures, principles, processes and core concepts) as "[impinging] *upon the capacity of societies to manage ecosystems, withstand environmental degradation as well as economic shocks, and rebuild and renew themselves afterwards*" [2] However, as a correlative to this negative role, law and the legal system also have the ability to promote resilient governance and management [3]. The focus for this positive role is often on the ability of law to foster adaptive governance and the benefits this would bring for environmental management, particularly in the face of increasing global climate change [3] [4] [5]. However, this paper focuses on the necessary primary step; understanding the law. If resilience researchers are to "*engage with the law as one of the factors that affects societies' capacity to engage with change,*" [2] then such researchers need first to identify the law and understand its impact on the processes being studied. Through the exploration of two case studies on legal research topics relating to water, this paper aims to explain the legal research methods available and identify the benefits to researchers in water resilience topics of adopting a socio-legal approach.

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2. METHODOLOGY

The two case studies presented in this paper provide an example of the two main legal research approaches; doctrinal and socio-legal. Through the exploration of these approaches in a practical context, including their advantages and disadvantages, the paper aims to elucidate the benefits for resilience researchers of engaging with legal research, and in particular, with socio-legal research. The first case study presented involved the study of the law in relation to flooding and, in particular, the availability of legal remedies to individuals to increase their resilience to flooding. The second case study considered the use of resources within water; namely fish. Focusing on the public right to fish and whether this right could be reframed as a tool to help increase the resilience of the resource to enable current and future generations to have the benefit of fish.

3. CASE STUDY ONE: FLOODING AND OUR RIGHTS

In response to severe flooding in the Somerset Levels in early 2014, then Prime Minister David Cameron stated that money was "*no object in* [the] *relief effort. Whatever money is needed for it will be spent*" [6]. The question raised by this statement (for legal researchers, at least) is whether the action taken by the government in response to the flooding of the Somerset Levels was motivated by the legal rights of those living and working in the area or rather by political considerations. If there is a public right to be defended from flooding, then the source of such a 'right' is not obvious on the face of the law. This case study considers the investigation of the law relating to flooding defence in England and Wales that was prompted by the statement above [7].

3.1 Doctrinal Research

This research adopted a doctrinal approach. The essence of such an approach is that the law is a distinct field of study that can be separated from outside influences such as politics, economics and morality. Furthermore, the crucial assumption for this approach is that the legal system is largely coherent and thus it is the role of the doctrinal researcher to uncover and explain this coherence [8]. The consequence of viewing the legal system as distinct and discrete is that the sources available to the doctrinal researcher are for the most part limited to primary sources of law; i.e. statute law and case law. A cursory glance at any number of examples of both of these shows that "*the messy work product of the judges and legislators requires a good deal of tidying up, of synthesis, analysis, restatement and critique*" [9]; providing a clear role for doctrinal analysis.

Nonetheless, the obvious criticism to make of the doctrinal approach is based on its view of the law as a closed system. By shutting out all consideration of moral, political, economic and other factors, the view of the doctrinal researcher is an internal view of the system, devoid of any context. Without considering the context in which rules were created, the purpose they were intended to serve or the effects they have in practice, the relevance of the conclusions of doctrinal research to any debate about the rules at issue is called into question [10].

3.2 Findings

The doctrinal research carried out for this project covered a diverse array of topics, drawing on both statutory law (focusing on the Flood and Water Management Act 2010) and common law (i.e. the system of precedent arising out of case law decided by judges). Statutory law was notable for the lack of legally binding duties placed on public bodies in relation to flood defences[11]. Some of the common law options considered, including riparian rights, nuisance, negligence, prescription and the Crown duty to maintain coastline, provided a small glimmer of hope to those benefiting from private flood defences that in certain, very limited, circumstances they would be able to enforce the maintenance and repair of those defences. However, none of these provide the basis for a duty to keep flood defences in repair and, furthermore, none are likely to extend to publicly owned flood defences [7].

The conclusion from the research was therefore that no general right to all to be protected from flooding exists at present in the English and Welsh legal system and so the response of the government in 2014, together with past and subsequent responses have been motivated by political considerations. This conclusion prompts concern for the difficult decisions to be made in the future as we move towards a world in which increasing numbers of the UK population will face flooding damage and disruption; when 'money is no object' will no longer be appropriate.

3.3 Lessons for Resilience Researchers

The conclusions of the research project can be helpful in a number of ways. For example, this project drew together the law on private flood defences to provide guidance for those whose property is protected by such flood defences as to when and how they might be able to enforce the repair and maintenance of those defences. However, as a piece of doctrinal research, the conclusions are limited by the inability to look beyond the legal system. Despite the lack of a right to be defended from flooding, the government, no doubt motivated by political and economic considerations, powered into action in the wake of recent floods caused by Storm Ciara and Storm Dennis in early 2020, offering a package of measures to flood hit areas, including grants to affected households and businesses to improve their resilience to future flooding [13]. The inability of doctrinal research to consider the social context of the law being studied means that these motivations cannot be studied and suggestions for how these motivations might play out in the future cannot be made.

4. CASE STUDY TWO: THE PUBLIC RIGHT TO FISH IN DEVON AND THE SEVERN

The public right to fish (also referred to as the public fishery) exists in English and Welsh common law and provides the right for all members of the public to fish in the sea and tidal waters (providing that any applicable legal rules and regulations are complied with). As part of the author's doctoral research, a case study of the district covered by the Devon and Severn Inshore Fisheries and Conservation Authority (IFCA) (the body responsible for the management of fisheries in coastal and tidal waters out to 6 nautical miles from the coast) was carried out, with the purpose of understanding how people involved in fishing in this district understood and experienced the public right to fish and how such views and experiences impacted upon the management of coastal fisheries.

The case study involved semi-structured interviews with 26 key informants, drawn from the commercial fishing sector, the recreational fishing sector, the conservation sector and those involved in the management of fisheries. Data published by the IFCA in relation to a recent byelaw restricting the use of nets for fishing within the district, together with the author's observations of the public meetings held by the IFCA management committee during the period of data collection, was also brought into the case study.

4.1 Socio-Legal Research

As can be seen from the introduction of the case study, this research travelled far outside the legal system and focused heavily on the social understanding of the law, something that a doctrinal approach would not be able to do. Instead, a socio-legal approach was adopted. This involves viewing the legal system as a social institution and taking account of "*the social effects of law, legal processes, institutions and services* … [together] *with the influence of social, political and economic factors on the law and legal institutions"* [14]. Not only is the social element of the legal system in full focus with a socio-legal approach, but often the research itself uses social science methods to investigate the topic at hand, an approach that has been described as "*doubling the social"* [15]. In the present case, the research used interviews and observation to collect data from participants, with the aim of finding out what *they* thought of the public right to fish and how *they* felt it should fit into the regulation and management of fisheries.

4.2 Findings

The data collected in this case study was analysed using a reflexive thematic analysis approach [16] that resulted in the generation of 5 themes telling the story of the data. These themes and their relationships are shown in the thematic map at figure 1.

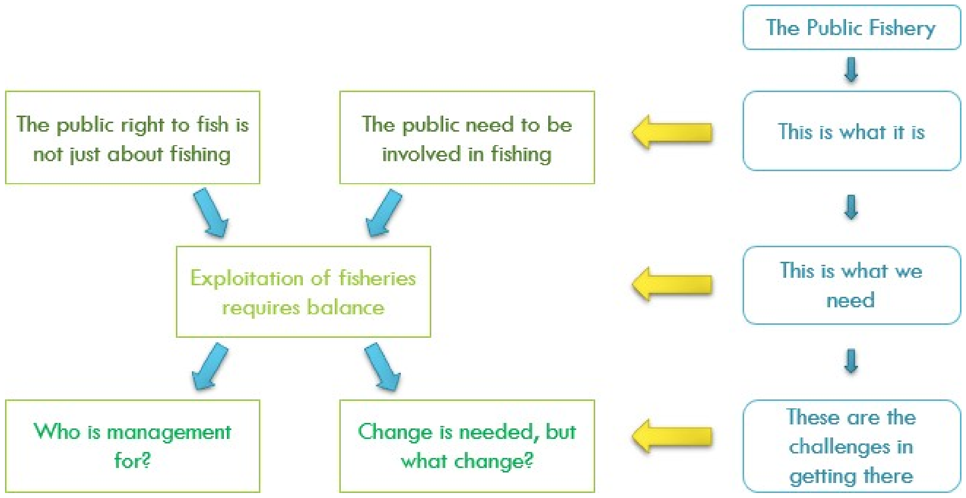

Fig. 1. Thematic map showing the themes generated (in green) and the relationships between them

Unlike the suggestions in the literature that the public right to fish provides a licence to commercial fishermen to overfish [17], the story of the data is one of a public right to fish that performs a valuable role in fisheries and society by acknowledging and protecting the public interest in the fishery resource and facilitating the identity of many coastal communities. The public right to fish is also a legal instrument that, if embraced, could help to reach the balance that was recognised by many of the participants to be the target of fisheries management. However to do so, any strategy will need to address the challenges identified both in terms of giving clear communication as to the purpose of management, being for the public as a whole, and in terms of bringing the divergent stakeholders together around a clear approach for everyone.

These aims could be achieved through framing the public fishery as a public trust asset. The public trust is a legal doctrine providing that certain resources – often relating to water – are held by the state on behalf of the public as a whole [18]. The public trust doctrine correlates with many of the themes identified in the research, including that the fishery resource is for everyone and that the public interest in the resource needs to be recognised. Adopting a public trust interpretation of the fishery therefore has potential to facilitate the balance required and address the challenges identified above.

4.3 Lessons for Resilience Researchers

By opening up the field of enquiry to the myriad of factors that interact with and co-constitute the legal system, socio-legal approaches to research are able to provide a much more relevant picture of the law and its effects than the traditional doctrinal approach. In the present case study, the doctrinal research carried out before the start of the case study confirmed that a coherent legal argument could be made for the existence of a public trust in respect of the public fishery. That argument on its own, however, is vulnerable to criticism that it is not how the fishery has been interpreted thus far by the judiciary or legislative and that is therefore unlikely to receive support. But, when considered in conjunction with the socio-legal research that suggests that those involved in fishing activities already interpret the public fishery in ways consistent with the notion of a public trust, then the argument becomes much stronger. It moves from an argument seeking to change the status of the fishery, towards one seeking the acknowledgement of the currently overlooked status of the fishery.

The more rounded and relevant results provided by socio-legal research are of clear benefit to legal researchers. However, they can also be of benefit to resilience researchers. Indeed, if ‘law’ is viewed as part of a “*continuum of social normativity,*” then socio-legal approaches to resilience research open up consideration to a wide range of “*conduct-shaping and thought directing rules and standards*” [19]. Thus, allowing researchers to understand the legal system and its role (both actual and potential) in the social-ecological systems that are under focus. Increased adoption of socio-legal approaches by non-legal researchers also has the added benefit of widening the audience for legal research beyond the discipline of law; an important step in enabling the discussions required regarding the choices that need to be made in adopting law and policy that moves us towards resilience [20], as discussed above in the context of flooding.

5. CONCLUSION

Clarvis et al suggest that research is needed “*to identify key measurable legal and institutional features that might promote resilient water governance and management in the face of climate change*” [3]. This paper has suggested that one route to achieving this aim is by resilience researchers adopting a socio-legal approach to research. Such approaches have the benefit of bringing the expertise of social researchers to problems relating to the legal system. They also help to bring together social, scientific and legal researchers with a common aim and thus to “[chip] *away*” at the “*institutional cultures of law and science,”* helping each to understand the other and work together to address the uncertainty and complexity both thrown up by social-ecological systems and needed in order to manage such systems sustainably [5].

ACKNOWLEDGEMENTS & COMPETING INTERESTS

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Rain gauges to rain gardens: exploring the role of urban drainage engineers with school children in Taunton

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ABSTRACT

Engaging children and young people with an increasing range of possible climate impacts and adaptations in positive, action-orientated ways is becoming essential for STEM and arts-based disciplines and organisations. Through funding received from the Royal Academy of Engineering's Ingenious programme, a group of engineers, public engagement professionals, teachers, students and their parents undertook a collaborative project at two schools in Taunton, UK. The Westcountry Women Working With Water (5W) project took a practical approach to exploring climate impacts with school children (ages 7-9) focusing on flooding, urban drainage and sustainable drainage systems (SuDS). To achieve the project's objectives, the 5W team co-produced engaging water and SuDS-focused activities: messing around with water, sand, soil, gravel, plants, specially-created 'SuDS Top Trumps', puddle treasure hunts and posters and stickers was lots of fun for everyone! Two SuDS designs were then co-produced and the SuDS installed at each school. Celebration events enabled parents and guardians to attend to ask questions and explore the installations. 17 events were held, 2 installations were achieved, 12 activities were devised, a 3-minute video was launched, 189 children, teachers and parents were engaged and 8 engineers were upskilled in STEM outreach and engagement. At the end of the project the children expressed they learnt so much about so many things and the 5W team learnt a lot about how to engage school children with STEM topics and how exhausting it can be to be a primary school teacher! This paper provides a project summary, evaluation overview and team reflections on working with children when exploring STEM-arts perspectives on living with environmental change.

Keywords: children, climate change, flooding, sustainable drainage, Taunton, water

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1. INTRODUCTION

Our emotional and physical wellbeing are maintained as long as we are connected to the natural world [1]. Awareness and knowledge (conscious or subconscious) of extreme weather events and climate change as disrupting these connections can create ‘eco-anxiety’ [2] and ‘eco-angst’ [3]. In addition, children and young people’s worldviews and norms are still forming and malleable to various influences [4]; through a longitudinal Finnish study [5] identified that worldviews are consolidated between the ages of 14 and 17. Consequently, engaging children and young people with an increasing range of possible climate impacts in positive, action-orientated ways is becoming essential in order to address increasing fears of future generations suffering negatively from eco-anxiety. Imaginative and immersive experiences as a child can last a life time and at a time where Our Planet faces a range of challenges, interactive, science-led and arts-based activities are beginning to emerge [6]. As well as highlighting the important role and value of science, technology, engineering and maths (‘STEM’) in identifying interventions for society to reduce the consequences of climate impacts, there is also the need to enhance gender diversity within STEM subjects (traditionally male-dominated) to enable creative and innovative interventions to be identified and designed in appropriate and inclusive ways [7]. Using these perspectives as theoretical starting points, The Royal Academy of Engineering-funded Westcountry Women Working With Water (5W) project took a practical approach to exploring climate impacts with school children (ages 7-9) in Taunton through the role urban drainage engineers play in our everyday ‘water’ lives. This paper provides a project summary, evaluation overview and team reflections on working with children when exploring STEM-arts perspectives on living with environmental change.

2. METHODOLOGY

The 5W project’s objectives were to: (1) explore the role engineers (and others) play in our everyday ‘water’ lives; (2) co-produce a set of workshops to enable the co-production of rain garden and rainwater management system designs; (3) get those systems installed; and (4) co-produce a programme of citizen science activities to keep the ‘water conversation’ going between the schools and the engineers. Undertaking these engagement objectives enabled the 5W team to achieve the project aim, which was to role model engineering and contemporary urban drainage engineering, as a creative endeavor accessible to all genders and backgrounds. To do this the 5W team identified a location that would significantly benefit from the project and established a methodology underpinned with co-production to undertake educational lesson planning, materials development, workshop delivery, sustainable drainage systems (SuDS) design and project evaluation.

2.1 Project Location

The large town of Taunton is located in Somerset, England, UK and suffers a past and projected future of flooding under changing climate scenarios [8, 9]. The town had already been assessed using twelve environmental, social, cultural and economic indicators as part of the Defra-funded Local Action Project, which had enabled strategic investment decisions to be made to improve the town’s environment. Additionally, EU funding was received as part of the Somerset Sponge project, which focused on Somerset as a case study for the larger Sponge 2020 project, tasked with taking action on water-related effects of climate change. Through Somerset Sponge, the Westcountry Rivers Trust began collaborating with local people to co-develop nature-based solutions to address surface water flooding. After discussions with researchers at the University of the West of England and the University of Exeter, the 5W project was proposed and secured funding to complement Sponge Somerset to specifically engage school children in areas of Taunton ranking low on the Index of Multiple Deprivation. The funding was secured from the Royal Academy of Engineering and aimed to role model urban drainage engineering in these communities, particularly to students, teachers and parents identifying as female, in order to demonstrate it is a profession that is accessible to all genders and backgrounds. The areas of Holway and Lyngford were self-selected (Figure 1), as the eco-champions of the schools in these areas responded to an open call for participation.

Fig. 1. Map of Taunton illustrating the Westcountry Women Working With Water (5W) project locations

2.2 Co-production workshops for lesson plans, materials and SuDS

The 5W team, comprised of engineers and public engagement professionals across different backgrounds, genders and ethnicities, focused on the urban water cycle, flooding and SuDS in Taunton. A co-production approach underpinned the project and followed two pathways: (i) co-producing lesson plans and materials amongst educational professionals, engagement professionals and engineering professionals and (ii) co-producing SuDS designs amongst the 5W team, school children, teachers and parents.

2.2.1 Lesson plans and materials

Enhancing engineers' opportunities to develop skills and experience in outreach and public engagement with schools and school children also enables role modeling of the tasks and responsibilities that engineers undertake. Consequently, the engineers from the University of the West of England, the University of Exeter and OTA Water (now part of SDS Ltd) and the educational and engagement professionals from the Westcountry Rivers Trust undertook co-production workshops to devise lesson plans that would meet the educational requirements for English National Curriculum Key Stage 2 whilst embedding the knowledge and experience of the engineers. Living with environmental change, urban drainage and SuDS are complex topics and therefore the 5W team had a lot of discussion and experimenting to break down and conceptualize different aspects through non-expert language (but keeping key technical terms where appropriate), practical activities and worksheets suitable for seven to nine-year olds. Lesson plans covered prior learning, learning objectives, links to the National Curriculum, vocabulary and a chronology of the lesson including activities, duration of each activity, resources and links to each learning objective. The first lesson devised introduced the concepts of the urban water cycle, flooding, SuDS, flow rate, storage and infiltration. Each of these concepts was demonstrated through an interactive activity that was shared between the 5W team and the children. For example, a rain gauge making activity, a water pipe flow rate activity and an activity using specially designed and made 'bucket boards', which enabled water to be poured into small buckets secured to a display board, each containing a different material to demonstrate how they (e.g. types of SuDS) have different infiltration rates, how that changes the flow rate of the water and the consequences that might have in different places. Messing around with water, sand, soil, gravel, concrete and plants to demonstrate how each alters an infiltration rate was lots of fun for everyone! The children quickly learnt that concrete and tarmac are not very good choices to help with urban drainage and surface water management! The first lesson plan was also complemented by the inclusion of the first Frankie the Flamingo book (The Mysterious Case of the Sinking Flamingo by Cath Hassell, illustrated by Jon Evans), which the children had read with their teachers before the first lesson and completed associated worksheets to introduce core concepts.

The second lesson comprised a ‘puddle treasure hunt’ and mapping activity to identify areas susceptible to flooding around the schools, more SuDS experiments and devising and using ‘SuDS Top Trumps’ and SuDS sticker posters. Top Trumps are a well-known children’s card game where each card contains a list of numerical data associated to a particular item, with the aim of the game being to compare the data to try to trump and win an opponent's card. The SuDs Top Trumps represented twelve different SuDS: green roof, green wall, raingarden, rainwater harvesting (RWH) system (large), RWH system (small), swale, raingarden planter, trees and tree pits, retention and detention ponds, wetlands, permeable paving and a vortex flow controller. Categories represented on the cards were storage, space, wildlife, look, cleans water, upkeep, water reuse and enjoyable, so the children and parents (who attended latter workshops) could compare the SuDS. Through playing the SuDS Top Trumps familiarity with the look, function and scale of the SuDS was enabled.

<u>2.2.2</u> <u>SuDS design and installation</u>

After the SuDS Top Trumps were played, SuDS sticker posters were introduced, which gave the children, teachers and parents the opportunity to vote on the types of feature they would like the SuDS in their school to have. Posters focused on the look, colour, smell, feel and function and captured votes in the form of stickers. The posters were used alongside the puddle treasure hunt maps, free drawing activities, surveys of parts of the school and technical input from the installers to devise the final designs. During the school holidays (due to project timings and health and safety requirements) the selected SuDS were installed, which comprised a RWH system and green wall in one school and a rain chain and raingarden in the other school. Everything except the plants was installed and on their return to school the children took part in planting workshops to add all the plants and learn about their function in the SuDS. At the suggestion of the children, the green wall was planted with edible plants to feed the school guinea pigs and the raingarden was planted with water loving plants to enable them to thrive in potentially boggy conditions. The third and final lesson was devised to be in the form of a ‘celebration event’, to officially ‘open’ the SuDS so the children could invite their parents to school to see them and share their learning (and to have cake of course!). The celebration events also included the second Frankie the Flamingo book, as Cath Hassell had also received RAE funding to produce The Mysterious Case of the Elephant That Forgot. It seemed synergetic for the two projects to complement each other and Cath supplied a copy of the book for each child, delivered the associated workshop at one school and trained the engineers to deliver the workshop at the other school. The workshop included broader engineering concepts, not just on urban drainage, to reinforce and strengthen learning about engineering shared to that point and to enable teachers to use it as springboard for further STEM lessons.

Fig. 2. Lesson in action, example lesson materials and photos of SuDS installed during the 5W project (poster lesson; example SuDS Top Trump card; example poster; green wall; rainwater harvesting system; rain chain and rain garden)

3. RESULTS AND DISCUSSION

The 5W project's workshops, lessons, installations and celebration events were successfully delivered between June 2018 and July 2019. At the beginning of the project targets and measures were implemented through which to evaluate success (these included short feedback questionnaires and interviews with children, teachers and parents – with full consent provided). Throughout and at the end of the project these targets and measures were assessed and a full final evaluation report compiled, which forms the basis for the following results and discussion.

In total 17 events were held, 2 installations were achieved, 12 activities were devised, a 3 minute video was launched (https://youtu.be/dCKun9A07Vs), 189 children, teachers and parents were engaged and 8 engineers (5 female and 3 BAME) were upskilled in STEM outreach and engagement. Each engineer participated in at least two types of activity (Table 1) to ensure they received a minimum level of training in relation to designing activities, engaging with children and parents, running activities (including practical demonstrations, working outdoors, leading educational games), facilitating question and answer sessions and all important classroom control (learning from the teachers was quite an enlightening experience for some!).

Table 1. Number of engineers that participated in each activity

Activity	Number of engineers
Planting in the SuDS	2
Final workshop/celebration event	5
Working outdoors (puddle treasure hunt)	5
Making rain gauges	5
Free drawing designs	6
Poster & stickers	6
SuDS Top Trumps	6
Q&As	6
Bucket boards	6
Water pipe flow rate	6

At the end of the project all engineers reported they had either some increased understanding or much better understanding of the range of engagement approaches and tools available for working with primary school children and seven stated they were very confident in talking to the general public about their work (one stated they were quite confident). The engineers stated the project also provided them with benefits such as improved communication skills, increased understanding of public attitudes to engineering, opportunities to network, new perspectives on their work and enhanced career opportunities. Reflecting on their experiences, the engineers commented:

- *"I have thoroughly enjoyed working with the children, teachers, parents and the 5W team on this project. I have developed a good understanding of how teachers calmly and effectively control their classes and how children engage with engineering, STEM and water-focused topics at Key Stage 2. Reading to the children whilst they were watching visuals related to the engineering and SuDS books and seeing how much they remembered and engaged with the questions afterwards was a particular highlight. They were also so enthusiastic in participating in all the activities and even remembered things months after each visit, which gave me a real sense of making a difference in their potential future engagement with civil/environmental engineering/geography/environmental sciences."*

- *"The opportunities to conduct knowledge transfer sessions and the importance of Sustainable Urban Drainage Systems (SUDS) to primary schools in England (Southwest) has been very inspiration and a rewarding one"*

- *“The 5W project provided me with an opportunity to engage directly with young students in environmental engineering projects, where in the past I have only worked with school officials. I have gained new insights into some useful methods of engagement and co-creation with this very important group which is critical for climate change adaptation and sustainable development”*

- *“This was a very enjoyable project working together with a great team of supportive people. It was also really lovely to see all the children participating and engaged in all the activities. Their enthusiasm was infectious and I hope we inspired a few children to think about engineering as a future career.”*

74% of the children learnt something new about engineering, over 60% of the children were inspired to want to find out more about engineering, including 67% of female pupils and 59% of children thought the activities were great. 85% of parents reported that they were more likely to encourage their children or family members to get involved with science and engineering subjects, which was really rewarding for the project as 30-40% of the pupils at the schools receive pupil premium. 5W provided a new perspective on engineering and what engineers do for children at a young age and their parents, encouraging their understanding and the role as a potential future career or profession:

- *“I learnt about what being an engineer can do for the planet.”*

- *“I learnt that the engineers help the floods which we have in Taunton.”*

- *“I learnt that you need to try lots of different ideas to get the best one.”*

- *“[the raingarden] brings more wildlife and it will inspire more people to become engineers.”*

The SuDS features installed at the school provide a legacy, which will continue to inspire future children, through their creative use of water, wildlife value and through the production of real-life scientific data and its use in key stage 1 and 2 activities. To ensure ongoing engagement, members of the 5W team delivered follow-up workshops to initiate a citizen science programme, focusing on rain gauge data at the school so the children can collect and use rainfall and runoff data to perform their own SuDS research (rain gauges were installed after the end of the project, but teething problems and then COVID-19 mean that this work is ongoing). From a 5W team point of view, communication was sometimes a challenge, especially for the engineers who were mainly involved with the school visits and less so with installation (completed by contractors). A lesson learnt would be to maintain regular communication and updates with the whole group (perhaps through an online forum/project management app) so everyone is aware of progress even if they are not directly involved in each step.

4. CONCLUSION

Through a detailed monitoring and evaluation programme, it was determined that the Westcountry Women Working With Water (5W) project achieved its objectives, which were to: (1) explore the role engineers (and others) play in our everyday ‘water’ lives; (2) co-produce a set of workshops/lessons to enable the co-production of rain garden and rainwater management system designs; (3) get those systems installed; and (4) co-produce a programme of citizen science activities to keep the ‘water conversation’ going between the schools and the engineers. Undertaking these engagement objectives enabled the 5W team to achieve the project aim, which was to role model engineering and in particular contemporary urban drainage engineering, as a creative endeavour accessible to all genders and backgrounds. Through a diversity of activities delivered through a series of lessons and workshops, which culminated in ‘celebration events’, the team brought together scientific and engineering theory, knowledge and experimentation with arts-based approaches and gaming. These activities culminated in the installation of a rain garden, green wall and RWH system, which form an ongoing focus for co-producing citizen science activities.

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Learn more about the project here: http://somerset-sponge.org/workshops-and-celebration-days-with-our-5w-schools/ and https://www.youtube.com/watch?v=dCKun9A07Vs
All the SPONGE2020 work and case studies are available here: https://www.urbangreenbluegrids.com/sponge/
The lesson plans and learning materials co-produced during the 5W project are available in the teachers notes for the book 'DRY: the diary of a water superhero', available from: https://issuu.com/uwebristol/docs/dry_the_diary_of_a_water_superhero and https://aboutdrought.info/educational-resources/ thanks to the RCUK-funded DRY Project: http://dryproject.co.uk/

COMPETING INTERESTS

The authors declare there are no conflicts of interest. The funders were not involved in the project design, data collection, evaluation or writing of the manuscript.

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#4. Resilience, policy & governance in urban & built environments

Improving the uptake of micro hydropower in water networks

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ABSTRACT

The abstraction, treatment and distribution of water typically has strict water quality and service delivery standards. However, this sector also has significant resource resilience implications in addition to being energy intensive. Further, the energy use in the water sector has direct and indirect greenhouse gas emissions which in turn results in climate change. In Europe, the EEA Technical report No 5/2014 roughly estimates the net consumption of 88 kWh/y/person for household component of urban water i.e. 5.5% of total electricity consumption or the each person leaving a 10 W light-bulb on constantly. In the UK, the water industry is the 4th most energy intensive sector using up to 3% of the total energy produced as at 2009. The concept of the water-energy nexus is underpinned by maximizing the potential and circularity of resources. Therefore, it is incumbent on water service providers to: 1. increase the efficiency of their networks, systems and processes; 2. Capture and reuse the energy potential within their water and wastewater networks and/or before 3. Exploring external renewable energy opportunities.

Opportunities for the first option includes improved pressure and leakage management, minimizing or running efficient pumping stations, upgrading and/or automating instrumentation and control systems and processes. Micro hydropower (MHP) offers the potential to deliver on the second point. It entails the use of turbines situated in water channels or pipes at key nodes in the network to generate power of between 5-100KW. This results in an energy source that is as continuous and reliable as the network itself i.e. does not rely on intermittent sunshine or wind. A resource assessment study in Ireland and the Atlantic Area regions of the UK found more than 20 GWh of energy per annum could be saved from public water in this region, in addition to other leakage and pressure management benefits. The resulting energy can also be directly used for sensors, instrumentations, pumps, valves and other hardware at these locations. In spite of these advantages, few water networks have considered or MHP systems in their networks.

This study investigates the reasons behind the limited adoption of micro hydropower in the EU's Atlantic Area region. Stakeholders in the UK, Ireland, Spain, Portugal and France are surveyed to explore the opportunities and barriers to the uptake of MHPs in water networks. Findings highlight policy, institutional, technical and social issues. The paper concludes by making integrated recommendations to support improved resource efficiency in water networks, as a contributor to global resource and climate action.

Keywords: Micro hydropower, water policy, resource efficiency, resilience, water networks

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Assessment of the Existing Energy Recovery Potential in Drinking and Wastewater Networks in Ireland, Scotland, Northern Ireland and Wales, using Micro-hydropower

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ABSTRACT

An assessment of the potential for micro-hydropower (MHP) installation in piped water networks was conducted across Ireland, Scotland, Northern Ireland and Wales, focused on the potential for electricity production and reductions in net energy consumption in drinking water and wastewater sectors. Data from 8263 water network sites were collected across Ireland, Northern Ireland, Scotland and Wales. Energy was identified as the potential recoverable from these sites using MHP technology. Estimates of the total energy recovery potential were also conducted by extrapolating results from the power output estimates from collected data compared to regions were data was unavailable. The total MHP potential was thus estimated as 241 GWh/yr, divided among Ireland (17.1 GWh/yr), Northern Ireland (8.5 GWh/yr), Scotland (206.8 GWh/yr) and Wales (8.6 GWh/yr). This total energy potential estimation could be further divided across the drinking water (97%) and wastewater (3%) sectors. In the context of the total energy consumption in piped water systems in the mentioned countries, this paper provides a high-level overview of the potential of the exploitation of MHP energy recovery on the energy efficiency and environmental impact of the water sector as a whole. This technique has shown the potential to reduce energy consumption in water networks by 1.9-2.5%. 11% of the sites with any potential identified had a power output capacity higher than 15 kW, representing 48% of the total estimated energy for the analysed sites. This therefore demonstrates that a significant potential for technically and economically viable MHP installations exists in both countries, which cumulatively could make a valuable contribution to net energy efficiency and CO_2 emission reductions.

Keywords: Water supply; Irrigation; Wastewater; Micro hydropower; energy efficiency.

1. INTRODUCTION

The global increase in energy consumption and related CO_2 emissions support the unquestionable need of a global transformation towards the promotion of the use of renewable energy sources [1]. The energy demand for extraction, supply and distribution of water, as well as water treatments in the urban sector implies a large amount of energy requirements. For that reason, several works have already focused on the study of the performance and design of hydraulic machines for micro-hydropower (MHP) generation [2] [3] [4], with the objective to generate energy from excess pressure in water distribution networks. In the wastewater treatment plants sector, the assessment of potential energy recovery for specific sites has also

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been addressed in several works [5][6]. In other cases, the evaluation of the potential energy recovery using MHP in water industry has been covered for drinking water and wastewater treatment plants partially in areas in the UK (Wales) and Ireland [7], showing an estimation of around 18 GWh per annum of recovered energy. Similar methodologies have been applied also in different sectors, such as irrigation networks, finding potential energy recovery and potential carbon savings of 270.5 MWh and 108 t CO_2 eq., respectively, for the Bembezar Margen Izquierda Irrigation District, in Southern Spain [8]. However, these studies cover partial areas, without making a comprehensive assessment of the potential for energy recovery at country level. This is due to the difficulty in collecting the necessary detailed data on water distribution networks.

This work points out the need to make projections of the potential for energy recovery in different sectors, based on available data, in order to be able to estimate the country's possible development in terms of renewable energy generation and thus, the reduction of CO_2 emissions. For this reason, this study proposes a simplified methodology for estimating the potential for energy recovery through MHP technology in water networks. The developed methodology was applied to drinking and wastewater networks in Ireland, Scotland, Northern Ireland and Wales for specific facilities for which information was available and providing an estimate for the rest of the region.

2. METHODOLOGY

2.1 Identification of potential MHP sites and energy recovery estimation

Usually, in water distribution networks excess pressure locations are managed by installing pressure reducing valves or Break Pressure Tanks, among others. At these locations, previous research has shown the possibility of installing MHP turbines to recover energy from excess pressure in pipes, or excess height in free surface flows, without affecting downstream processes. Thus, in order to carry out an estimation of the energy recovery potential in water distribution networks, it is necessary to firstly identify the possible points in the network, as well as to collect the flow and pressure data corresponding to each point. In this case, this information was collected from several water utilities and public organisations throughout Ireland, Northern Ireland, Scotland and Wales. The variability in the frequency of the recorded data by the different entities, forced the selection of annual average flow and pressure values as the most appropriate for carrying out this assessment. A database, summarized in Table 1, was generated with the collected data, comprising the number of potential sites for drinking water and wastewater networks, in the different countries. As shown, the drinking water sector presented a larger volume of initial data, with a total of 7728 sites, while for the wastewater sector, only information from 535 facilities in Ireland was available.

Table 1. Existing potential sites in drinking water and wastewater sectors for MHP energy recovery in Ireland, North Ireland, Scotland and Wales.

Country	Drinking Water	Wastewater	Total
Scotland	5351	0	5351
Northern Ireland	2154	0	2154
Ireland	44	535	579
Wales	179	0	179
Total	7728	535	8263

Based on flow and pressure data, the potential power generation by MHP in the different sites was estimated following Equation 1:

$$P = Q \cdot \rho \cdot g \cdot H \cdot \eta \qquad \text{Eqn. 1}$$

in which *P* represents the potential power output, in W, Q represents the average annual flow rate, expressed as $m^3 \cdot s^{-1}$, ρ is the density of the water, in $kg \cdot m^{-3}$, *g* is the acceleration due to gravity (9.81 $m \cdot s^{-2}$), *H* is the head available at the turbine location, in m, and η is the overall efficiency for the power plant. Based on previous works, a constant and conservative efficiency

of 0.50 was considered for these estimations, considering that only average flow data was available. Then, a selection of sites with MHP potential above 2 kW was made, as smaller installations were assumed not to be economically viable [9].
Finally, the yearly energy recovery potential was determined in both cases, drinking water and wastewater sectors, considering 24 h·day^{-1} and 365 days·year^{-1} of working time in all facilities examined.

2.2 MHP potential in Drinking water sector

Data about drinking water network facilities for Scotland, Northern Ireland, Ireland and Wales related to flow, head pressure and population covered, were collected. From flow and head pressure data, the potential MHP power output was determined following Equation 1. 69% of the potential sites were placed in Scotland, for which the original database assumed average flow and height in a significant number of cases where actual values were unknown. Once the potential for MHP was examined for existing site data, it was compared against the population served by each network. Then, based on this ratio, an extrapolated power potential and energy recovery potential for MHP for all the regions, were estimated according to the total population.

2.3 MHP potential in Wastewater sector

Wastewater network information was used to estimate the potential energy recovery for MHP, based on Equation 1. Data about wastewater treatment plants can normally be found in discharge licenses, which detail the maximum annual volume authorized to be discharged into the river. From these annual volumes, an average flow, considering again 24 h·day^{-1} and 365 days·year^{-1} of working time, was estimated. Once the power potential was estimated, the possibility of extrapolating the results to the uncovered areas of the different regions was also considered. For this, a linear correlation between the power potential estimated for the analyzed installations and the covered population for those wastewater treatment plants in Ireland were used to predict the total power potential in the sector for the entire regions.

3. RESULTS AND DISCUSSION

3.1 MHP potential in Drinking water sector

Table 2 summarizes the results obtained from data processing for the drinking water sector in the different regions, showing the power estimated (kW), population covered and total population for the selected regions, as well as the extrapolated power (kW) and energy potentials (GWh).

Table 2. Power potential estimations and extrapolated power and energy potentials for drinking water sector in the selected regions.

Country/ Region	Power estimated*	Population covered	Total population	Extr. power potential*	Extr. energy potential*
Scotland	23006	5373000	5438100	23284	204
N. Ireland	859	1809539	1810863	860	8
Ireland	668	1904000	4761865	1671	15
Wales	772	3056650	3138631	793	7
Total	25305	12143189	15149459	26608	233

* *Power data is expressed in kW while energy results are expressed in GWh*

A total power potential for MHP of 26608 kW was estimated from existing data for the drinking water sector in Scotland, N. Ireland, Ireland and Wales. From this total, Scotland, with 69% of the initial identified sites, represented 91% of the power estimated and 88% of the power and energy potentials extrapolated. As it was previously mentioned in the methodology section, no actual flow rate was available for the different elements and facilities listed at the Scotland database, so calculations were made with flow rates included in the original database, according to pipe diameters or flow rate assuming total property coverage was correct.

Moreover, in the case of H values, actual pressure differential was not available for all elements listed, so an average value of 47 m, from the PRV database, was used. In this case, for 3846 elements (72% of the total for Scotland), the average value for H was used, while the minimum and maximum pressure values were identified as 0.25 and 157, respectively. Northern Ireland was the following region with higher power potential estimated, with 859 kW, although in terms of extrapolated power potential, Ireland reached a higher value compared to Northern Ireland, with 1671 kW and 860 kW respectively, representing 6% and 3% of the total extrapolated energy potential, which reached 233 GWh. From the total number of sites (7728), 2411 presented power potentials higher than 2 kW, and 259 of them exceeded 15 kW.

3.2 MHP potential in Wastewater sector

Data on Ireland´s wastewater treatment plants were available for 535 different installations. Average annual flow rates and H allowed to estimate the power potential for MHP, which was then correlated with the populations served. From the total number of installations, only 2 of the cases presented power potential higher than 15 kW, while 15 of them exceeded the minimum of 2 kW of power previously established. The correlation power potential against population was linear, responding to Equation 2, with a R^2= 0.65:

$$P_{WW} = 5.88 \cdot 10^{-5} \cdot pop + 2.1397 \qquad \text{Eqn. 2}$$

in which P_{ww} represents the power potential for MHP in the wastewater sector, in kW and pop the population. With this correlation, the extrapolated power potential for the selected regions were determined, showed in Table 3, together with the extrapolated energy potential estimations.

Table 3. Extrapolated power, in kW, and annual energy, in GWh, potentials for wastewater sector in the selected regions.

Country/Region	Total population	Extr. power potential	Extr. energy potential
Scotland	5438100	322	2.8
N. Ireland	1810863	109	1.0
Ireland	4761865	282	2.5
Wales	3138631	187	1.6
Total	15149459	899	7.9

In this case, the total energy potential reached 7.9 GWh, representing Scotland the highest value, with 2.8 GWh followed by Ireland, with 2.5 GWh.

3.3 Total MHP potential

The results obtained after applying the detailed methodology showed a total annual energy recovery potential for MHP of 241 GWh for the regions analysed, which included Scotland (86%), Northern Ireland (4%), Ireland (7%), and Wales (4%). These figures represent a potential for reduction in the total energy consumption in the water networks around 1.9% and 2.5% for both Ireland and the set conformed by Scotland, Northern Ireland and Wales, respectively. The highest energy recovery potential came from the drinking sector, which represented 97% of the total.

Noting the strong impact on the results of the data obtained for Scotland, and considering the previously detailed assumptions made, a new breakdown by region and sector of the rest of the cases was also analysed. In this case, omitting Scotland for a partial total, the energy potential for MHP reached 34.2 GWh, from which 85% corresponded to the drinking water sector and the remaining 15% to the wastewater facilities. These results evidenced that drinking water sector presented a significantly higher energy recovery potential compared with the wastewater sector. Nevertheless, the ratio between the power potential estimated and the corresponding number of sites analysed (with power potential above 2 kW) was 10.5 kW/site and 14.6 kW/site for the drinking water sector and wastewater sector.

4. CONCLUSION

An assessment of the potential power production for MHP in Scotland, Norther Ireland, Wales and Ireland was estimated at 241 GWh/year for the regions of Scotland, Northern Ireland, Ireland and Wales, from which 97% corresponded to the drinking water sector, while the wastewater network represented the remaining 3%. This energy recovery potential corresponded to those sites in which the power potential was higher than 2 kW, a condition which was satisfied in 2411 sites from the total of 7728 and 15 sites from a total of 535 for the drinking water and wastewater sectors, respectively. From those, 259 sites presented power potential higher than 15 kW for drinking water sector, while 2 were the corresponding to the wastewater sector. These sites, with MHP potential over 15 kW, represented 48% of the total estimated energy for the analysed sites. These cases could therefore be readily exploitable using low-cost MHP technology such as pump-as-turbines or alternative approaches. The most potential for extrapolated energy potential was present in the drinking water networks. Wastewater treatment plant outfalls by contrast presented limited potential for exploitation.

ACKNOWLEDGEMENTS

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Comparison of Seasonal Variation in Rainy and Dry Per Capita Water Consumption in Freetown, Sierra Leone

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ABSTRACT

Ensuring sustainable urban water supply for third world countries requires an understanding on the factors affecting water consumption and technical evidence of individual consumption which can be used to design an improved water demand projection. Adequate access to piped water supply is a major challenge for many developing cities. This paper compared the seasonal water sources available for consumption; aimed at providing an estimate of per capita water end-use in the different household income groups in Freetown, Sierra Leone. The study used a questionnaire survey to gather household data for a total of 398 households.

In the per capita water consumption patterns of Freetown a seasonal variation was found. The average per capita water consumption varied from 115 litres per capita per day (l/p/d) in the rainy season to 89 litres per capita per day in the dry season depending on the available water sources to households. Using multiple (stepwise) regression, the data has been trained to develop statistical models for selecting the best predictor variable. The results show that the R^2 values increase significantly when the models were developed for each income group as a function of all (demographic, physical and water use) household characteristics.

Furthermore, the results revealed that the highest fraction of end use is showering (18%). This is not in agreement with many developing countries where toilet use represents the largest component of indoor end use. The findings provide the information on factors for consideration influencing future water demand.

Keywords: per capita water consumption; seasonal variation, water end-uses, Freetown, stepwise regression.

1. INTRODUCTION

Water stress is becoming a serious problem in many parts of the world. This is mainly due to increasing climate variation, demographic changes, population growth and urbanization [1]. In many developing cities especially in sub saharan Africa, access to piped borne water is inadequate and only 58% have piped connection in their dwelling [2]. Studies have analysed some of the factors impacting on domestic water demand in developed and developing countries. [3]identified number of occupants, household type, household size, use of appliances, presence of swimming pool and evaporative cooler as variables that contribute to the variability of household water use in Melbourne, Australia. In Makurdi Nigeria, [4] used multiple regression analysis to identify variables mainly; household size, gender, number of children and kitchen type as the significant factors influencing residential per capita water consumption.

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Freetown city is experiencing a severe water shortage which has initiated emergency solution by providing water in ten-thousand litres tanks to affected communities, tapping additional sources and fixing leaking pipes. The rise in its population, inadequate dam infrastructure coupled with seasonal variability is visible from long queues at water points, with varying sizes of collection containers and the long distance travelled mostly by women and children in search of water for daily use. Hence, the aim of this work was to determine the seasonal variation in per capita water consumption and household characteristics with an understanding to develop a model that will be useful in identifying the factors that influence per capita water use in urban and suburban settlements. The objectives are to Identify per capita water use habits across all household income groups by quantifying the volume of water consumed per day and further establish how much water is consumed indoor for different activities (e.g. bathing, toilet flushing, dishwashing) and outdoor tasks (e.g. vehicle washing) between seasons. This information is important to improve the accuracy in predicting and planning for seasonal urban water supply demand management.

2. MATERIAL AND METHODS

2.1 Study area

Freetown the coastal capital city lies along the western coastline of Sierra Leone located approximately on Latitude 8°29′02″ N and Longitude 13°28′47″ W. The climate is tropical and humid all year with temperatures averaging 26°C to 32.5°C and relative humidity ranges from an average of 80% during the wet season to about 50% during the dry season. It has a population of 1.055 million people which has been divided into four income groups. The primary source of water supply in Freetown is piped water from the Guma Valley Water Company (GVWC), which is the only service provider.

2.1.1 Data collection survey

Data for this research was collected using multiple-choice format questionnaires containing over 80 standard questions. A total of 550 questionnaires were distributed in August 2017 and April 2018 for the rain and dry season survey respectively. University students were identified to complete the questionnaires on behalf of their households. The key variables investigated include the socio-demographic characteristics (age, gender, education and income); physical characteristics (number of rooms, vehicles, bathrooms, toilets and built up area); water use habits and ease of access (indoor volume, outdoor volume, collection containers, time to fetch, distance to source, water storage facility). 398 questionnaires were received coded and imported into IBM SPSS statistics V25.0 for analysis. MS Excel was used to present the results in charts and table format.

2.1.1.1 *Data analysis*

The investigated households were categorised into four household income groups and were analysed separately to determine their daily per capita water consumption in litres per day. Using the dataset, 20 statistical models were developed using multiple regression (stepwise) technique to select the best combination of household (demographic, physical and water use) characteristics to construct the best fit model based on strong statistical foundations.

3. RESULTS AND DISCUSSION

3.1 Seasonal Variability and Impact of average Per Capita Water Consumption

Figure 1 presents the frequency distribution and cumulative frequency of per capita average water consumption for all surveyed households during rain and dry season. From this figure, it can be seen that the number of households which consumes more than 93 l/p/d is decreased from 71% in rain to 6% in dry. Analysis of the dry season survey shows that the daily per capita average water consumption is mainly between 26 l/p/d to 75 l/p/d compared to that in rainy season, which is between 75 l/p/d to 120 l/p/d. Further analysis revealed that majority of the consumption is lower in the dry season because of water scarcity and limited alternative water sources. Pipe water supply is insufficient and households have to go in search for other sources of water for their needs. The analysis revealed that productive time is lost to trekking and queuing for long hours to collect daily water use. Figure 2 present the percentages of households distances and time spent to access their daily water for household use.

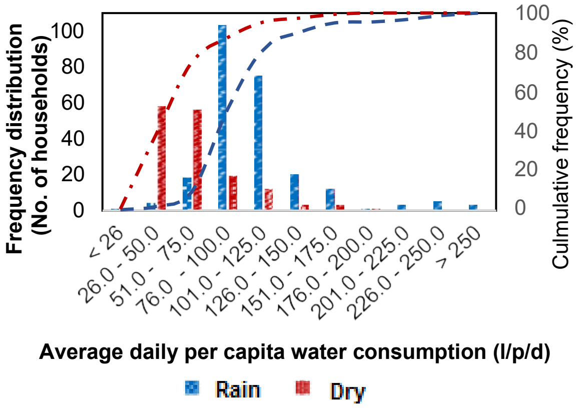

Fig. 1. Seasonal variabiloity of per capita average water consumption

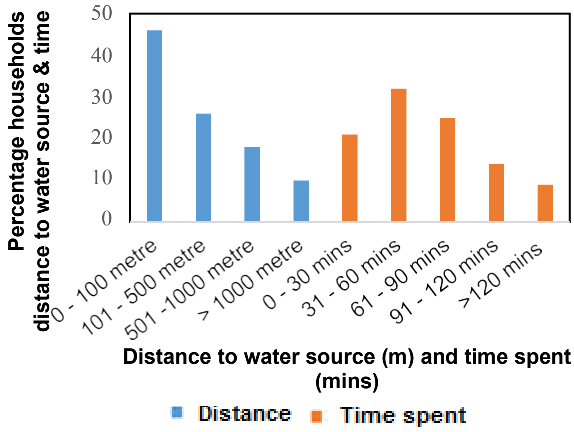

Fig. 2. Percentages of household distance to water sources and time spent to fetch water

Table 1 present the statistical comparison for indoor and outdoor water consumption. There is a moderate significant difference for showering. A two-tailed t-test at 95% confidence interval showed p values of bathing, cistern flushing, latrine use, hand washing, pour flush use and house cleaning higher than 0.05. This explains that there is no statistically significant difference between consumption in rainy and dry season and therefore they are less sensitive to seasonality. Equally, for showering, dishwashing, clothes washing, drinking, cooking, vehicle washing and garden watering, there is statistically significant difference ($p<0.05$) between the seasons.

Table 1. Statistical comparison of water end-uses between rainy and dry season (l/p/d)

Water end-use		Average water consumption (l/p/d) Rainy	Dry	Difference (rain-dry)	t value	Significant (2-tailed) (p)
Indoor	Showering	30.00	21.83	8.17	2.243	0.026 *
	Bathing	20.70	16.50	4.20	-1.062	0.290 **
	Hand basin taps	8.04	5.19	2.85	-1.043	0.299 **
	Cistern flush	14.37	1.37	3.00	1.009	0.315 **
	Latrine use	5.68	5.40	0.28	-1.705	0.090 **
	Pour flush use	8.96	8.41	0.55	1.232	0.220 **
	Dishwashing	8.40	7.64	0.76	8.514	0.000 *
	Clothes washing	19.25	15.43	3.82	2.827	0.005 *
	Drinking	4.38	3.78	0.60	-2.244	0.026 *
	Cooking	10.83	14.15	-3.32	4.121	0.000 *
Outdoor	House cleaning	8.96	6.60	2.36	-0.150	0.881 **
	Vehicle washing	11.53	10.25	1.28	1.276	0.020 *
	Garden watering	0.00	9.18	-9.18	-2.695	0.013*

*= significantly difference between rainy and dry
**= not significantly difference between rainy and dry
l/p/d = litres per capita per day

3.1.1 Modelled daily per capita water usage

A multiple linear regression (STEPWISE) technique was developed to determine the best subset model for daily per capita water use as a function of socio-demographic, physical and water use characteristics. The predictions from these models show that the R2 value and trend-lines improve when the water consumption data was disaggregated into the various income groups.

3.1.1.1 Discussion

The surveys revealed that frequency and duration of pipe water flow is a major concern for households in the study area. Water is rationed to all areas in the City with no household getting 24-hour supply. In the rainy season, households receive supplies on alternate days, about 4 times a week. In the dry season the situation is even more critical as households receive less supplies once or twice a week, or none at all. Only households with piped water have indicated the use of showers, hand wash basins and cistern toilets. All households do make use of alternative water sources (wells, springs, gravity and stream) and have a preference for the different end uses. The highest distribution fraction is shower (18%). This is in contrast to many developing countries where toilet use consistently represents the largest component of indoor end use [5].

4. CONCLUSION

The study establishes that a seasonal variation was found in the per capita water consumption patterns of Freetown. Average per capita water consumption varied from 115 l/p/d in the rainy season to 89 l/p/d in the dry season. The highest water consumption is from shower, approximately 30 l/p/d in rain season and 22 l/p/d in the dry season. Household income does influence water consumption poorer households use less water as they have fewer storage containers and transport assets. The rain water consumption estimation models ($R^{2)}$ are more improved than the dry model. Distance and time spent to collect water supply appear to be strong influencing factors impacting future water demand.

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COMPETING INTERESTS

None declared

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Water Use in University Restaurants: A Case Study in Goiânia

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ABSTRACT

The water situation that afflicts various regions around the world has made it mandatory to use actions that promote water conservation in buildings of different uses. Knowing how water is used in buildings has been the premise for planning these actions that promote water conservation and how to manage economic resources in a balanced way. Due to different characteristics, each typology should be investigated in detail, thus allowing to know how water is used as well as the degree of awareness of the population involved. Thus, it stands out the typology of food preparation, which consume a lot of water and that has few studies developed. Thus, this paper aims to describe how water consumption occurs in a university restaurant, located in the city of Goiânia, Brazil. Through interviews, measurements and observation forms, we characterized the uses of environmental hygiene and preparation of various types of food, allowing to verify which activities are the largest consumers and proposals to reduce water consumption in this restaurant. It is hoped that this work will serve as references for future work on this typology.

Keywords: water consumption, restaurants, water efficiency, water habits

1. INTRODUCTION

According to data from the World Health Organization and the United Nations Children's Fund (2019) [1], water scarcity today affects 1 in every 3 inhabitants on the planet. This scarcity is so high that the United Nations (2019) has established access to Clean Water and Sanitation as one of the 17 Sustainable Development Goals (SDGs) [2].

In this scarcity scenario, the efforts of universities around the world to study ways to rationalize the use of water (PURA-USP, Águapura-UFBA) [3,4] stand out. At the Federal University of Goiás (UFG), through Sustainable UFG, program created to encourage and raise awareness in the university community around sustainable practices, a growing focus has been given to the water use issue at the University Restaurant (RU).

The RUs are part of the Federal Government's assistance system to the Federal Institutions of Higher Education (IFES), which aims to provide low-cost meals to the academic community, thus reducing the dropout rate. According to the classification presented by Lippel [5], RUs can be classified as buffet self-service restaurants, with the difference that the amount paid is fixed and that there is a portioning of the protein dish, contrary to what happens, traditionally, in buffets.

Gonçalves et al [6], classify restaurants as major consumers of water. The authors affirmed

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that for the evaluation of the Consumption Indicator (CI) of restaurants (in L/meal), it is necessary to consider the typology of the building (restaurant itself, hotel, hospital, factory restaurant, etc.), because these values vary widely, including between different types of meal. Despite this, the literature has a value of 25 L / meal [7]. According to Dziegielewski et al [8], the greatest use of water in restaurants is associated with activities that occur in the kitchen (Figure 1).

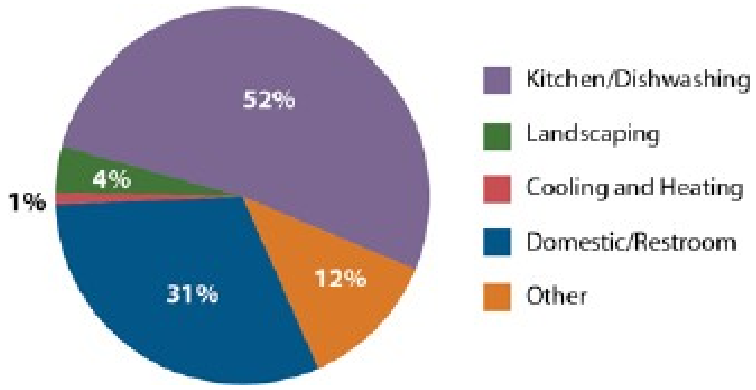

Figure 1. End Uses of Water in Restaurants [10]

These activities developed in the kitchens were studied in an industrial kitchen by Nogueira [9] in a study that was part of a policy of conservation and rational use of water developed by the Basic Sanitation Company of the State of São Paulo - SABESP (Table 1).

Table 1. Water consumption surveyed per restaurant kitchen activity [9]

Activities	Consumption per meal		% of
	Measured	Approximate	Total
Trays, plates and larger utensils cleaning	25,1 L	25 L	77,6
Hygiene of leaf vegetables	5,05 L	5 L	15,5
Food preparation	2 L	2 L	6,2
Restroom for kitchen workers and watter bottles for tables	0,19 L	0,2 L	0,7
TOTAL SURVEYED	32,34 L	32,2 L	100,0

In the same aspect of assessing water consumption, Murakawa, Takata and Nishina [11] conducted a survey with the objective of developing a calculation method for the volume of water demanded in restaurants. According to the authors, it is difficult to estimate the demand for water in the entire restaurant since this volume is variable and quite complex to quantify. However, it is possible to make it in kitchens and, as concluded in the research, use this volume to estimate the volume consumed in the entire restaurant.

This type of restaurant, still little explored in the literature, represents one of the biggest consumptions of Campus I. This work, therefore, has the objective of estimating the water consumption of University Restaurants with a case study in the RU of Campus I of UFG.

2. METHODOLOGY

This research was divided into 4 stages (Figure 2). The first stage was the choice and characterization of the chosen RU. The second and third stages consisted of data collection. Finally, in the fourth stage, the treatment and analusi of the data obtained.

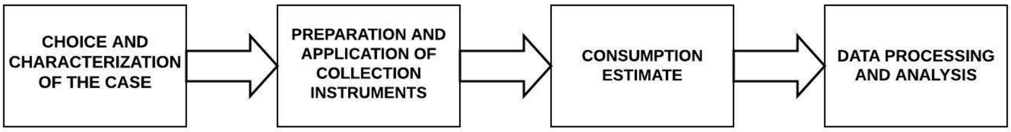

Figure 2. Research flowchart (Own authorship)

2.1 Choice and characterization of the case

For the case study of this work, the RU of Campus I at UFG was chosen. This campus is located in the East University District, in Goiânia and has 5 blocks (62, 68, 71, 86 and 87). The RU is located in block 71 (Figure 2) and, according to data from the university, presents approximately 60% of the water consumption of this campus.

Figure 2. Block division of the campus of UFG [12]

Currently, water consumption in the RU is distributed throughout the 3 served meals - breakfast, lunch and dinner (Table 2). Its opening hours are from 6:00 am to 7:30 pm.

Table 2. Meal Distribution Schedule [13]

Meal	Distribution Schedule
Breakfast (Monday to Saturday)	6:00 am to 8:00 am
Lunch (Monday to Saturday)	10:45 am to 2:00 pm
Dinner (Monday to Friday)	5:00 pm to 7:30 pm

In 2018, 319,088 meals were served in the RU. This distribution, however, was not uniform and varied (Figure 3). This variation is explained by the academic calendar. January, February, July and December correspond to the vacation months of undergraduate students, the largest consumers in the RU. In these months, RU consumption is limited to graduate students, workers and students participating in the Student Assistance Program. In the other months, the number of meals served increases due to the return to school.

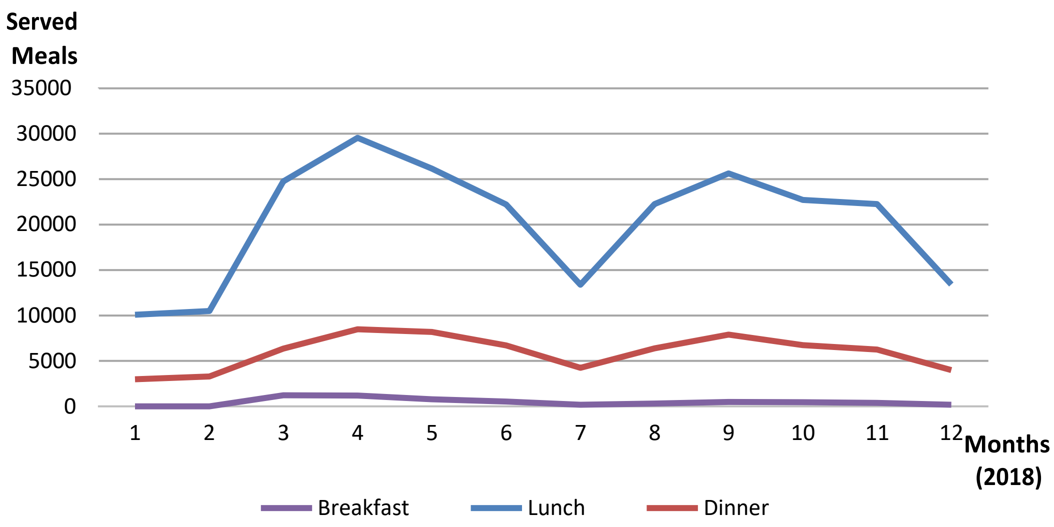

Figure 3. Annual distribution of meals served in 2018 (Personal communication)

2.2 Preparation and application of collection instruments

This step consisted in the elaboration of a form to facilitate the collection of information regarding the habits and procedures adopted in the RU. The questions asked were about the processes ("Is this activity standardized?" and "How is this activity carried out? Describe it."), about the times of the activities ("Does this activity have a specific time to be done? If yes, which one? If not, is it possible to estimate a time? ") and its frequency during the week ("On what days of the week do these activities take place?").

In addition to the questions asked for the responsible nutritionist and workers, the procedures adopted for activities involving water were also observed, using a stopwatch and a fixed volume container for necessary measurements. The questions and observations took place during 4 technical visits to the RU, all at the end of lunch so that it was possible to observe both the cleaning activities after lunch and the preparation activities for dinner.

2.3 Consumption estimation

Since the RU does not have a water meter for individual measurement, only estimates of water consumption were made for each activity. In the hygiene activity, the volume estimate was made based on information provided by the nutritionist. In the food preparation activity, the manufacturer of the industrial cookware used for cooking was also consulted and compared with the answers about the volume of water consumed given by the employees. In the pan washing activity, the time needed for the tap to fill a container with a fixed volume of 500 mL was measured with a stopwatch, making it possible to obtain the flow rate of the tap. In the activity of washing trays and cutlery, in addition to the 500 mL container, it was also necessary to consult the manufacturer of the washing machine to obtain the volume per wash cycle, since in addition to running water, this machine is used for asepsis of the trays and cutlery... Finally, in the activity of cleaning the floor, the capacity of the buckets used was measured and through the amount of full buckets used for cleaning, observed at the site, we found the total volume of water consumed in this activity.

2.4 Data processing and analysis

In this step, the data acquired during field visits were processed in order to obtain the total estimated volume consumed by each activity per day or week and thus determine the restaurant's CI. By means of graphs and tables, it was possible to compare the water-consuming activities of the RU and between the resulting and the expected CI, which appears in the literature. For data processing, the number of meals served in October 2018 and the menu served during October 2019 (month of visits) were considered. From this menu, standard foods were defined to be adopted in the considerations made for each estimate. The answers obtained for the questions asked during visits were also taken into account and the activities that in total corresponded to less than 5% of the restaurant's total water consumption were disregarded.

3. RESULTS

The investigation of the use of water in the restaurant was described in 4 activities, comprised of food hygiene, food preparation, utensil hygiene and floor cleaning. Each of these is detailed below.

3.1 Food hygiene

The cleaning activity is divided into three stages. Initially, fruits, vegetables, greens and leaf vegetables are rinsed under running water. Then, these foods go through 1 soak in sodium hypochlorite solution. Leaf vegetables go through 3 soaks to ensure proper hygiene. After the soaks, the food also goes through a second rinse under running water. The sink used for sinking has a flow rate of 0.14 L / s. The rinsing time was measured during the observations. To estimate the volume consumed in soaks, it was necessary to calculate the number of bowls used. The number of bowls was obtained from the amount of food served daily, the average density of the food and the volume occupied by the food in the bowl. The bowls used had a capacity of 40L, in which 20L was occupied by the food and the other 20L occupied by solution

Table 3 shows the estimated total volumes found in the surveys carried out for one working day.

Table 3. Estimated water volume consumed in food hygiene in one working day

Meal	Food	Number of bowls	Number of soaks	Water volume per amount of soaks (L)	Total rinse time (min)	Water volume in rinse (L)	Total volume (L)
Breakfast	Fruits	2	1	40	2	17	57
Lunch	Fruits	21	1	420	10	84	504
	Greens/Vegetables	58	1	1160	10	84	1244
	Leaf vegetables	7	3	420	10	84	504
Dinner	Fruits	7	1	140	3	26	166
	Greens/Vegetables	20	1	400	3	28	428
	Leaf vegetables	2	3	120	3	24	144
					Daily total volume (L/day)		3046

3.2 Food preparation

The only water consumed in the preparation of breakfast is in the coffee with and without sugar and tea. Each drink is served in a 12 L bottle. The bottles are not refilled throughout the breakfast. During the weekends the same bottles are used.

At lunch, the foods that use water in their preparation are rice, beans, grains, vegetables. The volume of water used in the preparation of meat is very irrelevant compared to the volume used in the preparation of other foods, since cooked meats are prepared only by “dripping” water and frying and, therefore, the water consumed was not considered in this estimate.

During lunch, approximately 70 kg of rice is made daily - between white and brown rice. For this quantity, 2 industrial water cauldrons are used, with a capacity of 300 L. In cooking beans, only one cauldron with a volume of 200 L for 50 kg is used. The remaining grains, served in the ovolactovegetarian and vegan options, were considered to be served at a frequency of 4 times a week and a quantity of 15 kg per day. Soy protein needs only hydration with water, while other grains (such as chickpeas and lentils) are hydrated and cooked with water. Regarding greens, an average of 600 kg per day was considered, which are also cooked using water.

The drink served at lunch and dinner is in the form of concentrated juice, mixed with water in a proportion of 1:6, as recommended by the manufacturer. At lunch, 7 containers of 5 L of concentrated juice are served. Therefore, the amount of water used in the preparation of juices for lunch is 210 L.

Based on 2018 data on the number of meals served, a ratio between dinner and lunch was calculated and found to be of 30%. This proportion was then used to estimate the volume of water consumed at dinner and also on Saturdays, since, according to the restaurant, the quantities of meals served are similar. Table 4 shows the estimated volumes for preparing food or drink obtained by measuring the time of use and the total volume per week.

Table 4. Estimated water volume consumed in food and drink preparation per week

	Food/Drink	Water volume consumed in one working day (L/day)	Water volume consumed on Saturday (L/day)	Total water volume per type of food/drink (L/week)
Breakfast	Coffee	24	24	144
	Tea	12	12	72
Lunch	Rice	600	180	3180
	Beans	200	60	1060
	Grains	21	6	90
	Greens and Vegetables	2264	679	12000
	Juice	210	63	1113
Dinner	Rice	180	-	900
	Beans	60	-	300
	Grains	6	-	19
	Greens and Vegetables	679	-	3396
	Juice	63	-	315
		Total water volume (L/week)		22589

3.3 Utensil hygiene

The activity of cleaning utensils was subdivided into three other activities with different characteristics: pans washing, trays washing and cutlery washing.

3.3.1 Pan washing

The washing of pans is done in a tap with a flow rate of 0.2 L / s. Based on timed measurements and observations, it was found that the tap used was open for 9 minutes in 1 hour (15% of the time). Since this activity is not performed throughout the 13 hours in which the restaurant stays open, the workload considered for this activity was 8 hours/day during weekdays and 4 hours/day during weekends. This estimation was validaded by the workers. The data used to calculate the estimated volume consumed are shown inTable 5.

Table 5. Estimated water volume consumed in pan washing per week (Own authorship)

Flow rate (L/s)	Usage Time (h)		Total Volume (L/week)
	Weekdays	Saturday	
0,2	1,2	0,6	4752,0

3.3.2 Tray washing

Tray washing is done in two stages. The first is made with a tap with a flow rate of 0.17 L / s. At lunchtime, this tap is kept open from 11 am to 3 pm approximately. In the second stage, the trays go through the second washing in a machine. The capacity of this machine is 9 trays, which go through 1 cycle in which 2.4 L of water are consumed. The total number of meals served in October 2018 in the RU was 30127 meals. To estimate water consumption during dinner and weekends, the ratio of 30% was added in the 4 hours in which the tap is opened during lunch. For breakfast, the same ratio calculated for dinner, was also calculated for breakfast.This ratio was found to be of 2% and was also added in the 4 hours. The data used to calculate the estimated volume consumed in this activity are shown in Table 6.

Table 6. Estimated water volume consumed in tray washing per week

Tap			Washing Machine				Total Volume (L/week)
Flow rate (L/s)	Usage Time (h)		Quantity (units/month)	Capacity	Number of cycles	Water volume consumed (L/cycle)	
	Weekdays	Saturday					
0,17	5,3	1,2	30127	9	1	2,4	18899,7

3.3.3 Cutlery washing

The washing of cutlery differs from other washes in a way that it doesn't need to go through the tap. Its washing is done exclusively by the machine. As informed by the workers, each support loaded with cutlery goes through 3 cycles, each one consuming 2,4 L. The number of cutlery used for this estimation was considered to be twice the number of meals served in the month. The machine capacity was obtained in the manufacturer's manual. The data used to calculate the estimated volume consumed in this activity are shown in Table 7.

Table 7. Estimated water volume consumed in cutlery washing per week

Quantity (units/week)	Capacity (units)	Number of cycles	Water volume consumed (L/cycle)	Total Volume (L/week)
15063,5	240	3	2,4	451,9

3.4 Floor Cleaning

The RU can be divided into 5 environments that are washed throughout the week with different frequencies and different ways. Some environments are washed only with soap and water and others are sometimes washed with soap and water, sometimes they are cleaned with a damp cloth. A bucket is used for both forms of washing. The volume of water was measured by observing how many times the bucket is filled. Table 8, shows the 5 environments, with their respective frequencies, ways of washing and estimating the volume of water consumed during a week.

Table 8. Estimated water volume consumed in the floor cleaning activity per week (Own authorship)

Rooms	Area (m^2)	Frequency of cleaning with water (times/week)	Volume of water use per week (L)	Frequency of cleaning with damp cloth (times/week)	Volume of water use with damp cloth per week (L)	Volume consumed (L/week)
Kitchen	217,14	22	2177,56	-	-	2177,56
Dinning Hall 1	177,71	2	162,01	17	255,00	417,01
Dinning Hall 2	96,98	2	88,41	5	75,00	163,41
Self-service 1	98,72	17	765,00	-	-	765,00
Self-service 2	49,41	5	112,61	-	-	112,61
				Total volume (L/week)		3635,60

3.5 Analysis of results/Discussion

By analizing the activities that occur in the RU, the utensilils´s cleaning and food preparation were the one that most consumed water, with a difference of only 3% between them (Figure 4). It was already expected that the first activity would consume the largest volume of water, as verified in Nogueira [9]. However, the high consumption of the second activity was not expected and this can be explained, in part, by the fact that a pressure cooker is not used in the preparation of some foods. Instead, foods that would need it to speed up cooking, undergo a hydration process, which ends up consuming more water, since the water is not reused. The third activity with the highest consumption is food hygiene and, finally, washing environments. The latter can be explained due to the fact that the washing of most environments is almost always done using a damp cloth.

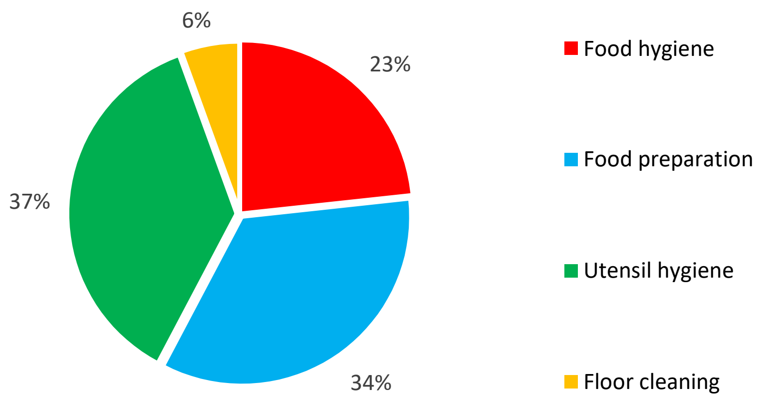

Figure 4. End use of water in the RU (Own authorship)

The CI obtained according to the measured values was 8.7 L / meal. It was calculated based on the meals served in the month of October 2018, since data on the number of meals served in October 2019 were not obtained and due to seasonality over a year in the number of meals, it was preferred to use the data from the same month of the previous year. The value suggested by the literature for restaurants is 25 L / meal [7] or 20 to 30 L / meal [14]. However, water consumption can vary between types and even buildings within the same type [15] and in the literature other CI values for restaurants in the order of 10 L / meal have already been found [16, 17].

Considering that the CI obtained was significantly lower than that presented by well-known literature, one can think about what caused this difference. First, the difficulty in measuring the volume of water consumed for each activity presented. This difficulty is due to the great variation that occurs in the way of using water and the non-standardization of some processes. Another reason would be the lack of an individual water meter to measure water consumption only in the RU, which would make it easier to measure the actual consumption of the restaurant and perhaps even to identify leaks and wastes. And finally, the simplicity of the service offered, that is, the non-existence of several menus or dishes that can be consumed by users, resulting in little variation of dishes, while other restaurants have several choices for customers. In addition, the largest area of the restaurant is little washed with water, while most restaurants are always washed this way.

4. CONCLUSION

At UFG Campus I located in Goiânia, the University Restaurant stands out for its high water consumption, due to the activities developed in this building, which are naturally large consumers. In order to be able to act to reduce water consumption and costs on Campus I, it is important to know and study the consumption of the RU, making it possible to draw up action plans to reduce consumption. Although the objective of this work has been achieved, the results found were not compatible with the expected, since the CI value found was considerably lower than the traditional values in the literature. Even so, it cannot be said that the results obtained are invalid, since other studies within the typology of restaurants also showed lower values for this indicator compared to the traditional ones.

In this work, it was possible to observe the difference in the consumption of common restaurants and a RU and to identify high water consumption activities. For future work, it is suggested to study these high consumption activities in depth as well as to propose ways to reduce consumption. In addition, the installation of one or more water meters for individual and daily flow rate measurements would allow to enrich the results already presented and, possibly, identify sources of waste and leaks in building installations.

Knowing and characterizing the consumption of water in this specific type of restaurant is important not only because it can contribute data to the literature, which is still poorly consolidated, but also because it allows the creation of action plans aimed at reducing water consumption and its costs. This reduction would make it possible to make better use of the money saved and distribute the amount saved to other users more fairly, thus contributing to the preservation of the environment and universal access to water [18].

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Keyword Index

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