Sustainability

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ABSTRACT: Selected 2016 publications on the focus of Sustainability are reviewed and discussed here. The followings are the topics presented:

- Sustainable water and wastewater utilities
- Sustainable water resources management
- Stormwater and green infrastructure
- Sustainability in water and wastewater treatment
- Life cycle assessment (LCA) applications
- Sustainability for water and energy,
- Sustainability and asset management

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Sustainable Water and Wastewater Utilities

The service (product) and delivery process can be changed incrementally and radically by the innovation. For British Water and Sewerage Companies, they seek to change infrastructure and improve the sustainability of service delivery within a comparatively regulated framework. Tanner et al. (2016) provided an understanding of the factors for the development and adoption of infrastructure investment process innovations in the context of water utilities concerned with water and sewerage service delivery. Their paper documents the process and results from an inductive research program undertaken within a large privately owned company to facilitate infrastructure investment process innovation. Small to medium sized water utilities face serious challenges to meet broad sustainability objectives. Most of these utilities are unable to address the performance gaps for various functional components. Haider et al. (2016) developed an intra-utility performance management model which is conceptualized and developed for effective decision making at utility and top levels. The model is implemented for a medium sized utility with three sub-systems in the Okanagan Basin (BC, Canada). The results show the model's practicality to achieve sustainable performance for small to medium sized water utilities.

Due to climate change, population growth, and other factors, water management becomes more complicated in the American West cities. One way to improve water management practices is to develop collaborative relationships among stakeholders. One importantly underdeveloped collaborative area is for the relationship between university researchers and water utilities. To develop collaborative relationships among multiple stakeholders at multiple scales, Crow-Miller et al. (2016) conducted a pilot survey, and interviewed with representative water managers and university researchers from American West cities. They identify the barriers to establishing collaborative platforms from which utilities and university researchers can work together to tackle challenges for sustainable urban water management. They developed an integrated model for university-utility collaborations. Rating and ranking water companies can utilize performance indicators (PIs) in the benchmarking process. However, a holistic assessment of company performance cannot be provided by a set of individual PIs from multiple perspectives. A multidimensional performance evaluation of water companies can be achieved by combining the PIs into a synthetic indicator. Although the concept of sustainability involves economic, environmental and social criteria, most of the previous studies have not considered these dimensions simultaneously. Molinos-Senante et al. (2016) discuss a process of indicator combination using two approaches from a holistic view to compare and evaluate the sustainability of Water Company. The techniques and results may be used as a way of improving the benchmarking process in water industries, and providing valuable contributions on most efficient steps to water company decision-makers for improving the sustainability of urban water services.

The adoption of new environmentally-friendly technologies is becoming a key issue in both public debate and policy arenas. Garrone et al. (2016) discussed wastewater utilities' innovation adoption, and studied why stringent environmental regulations are not sufficient to support it. The nature of highly specific infrastructures and the consequent exposure of utilities to political and institutional influences had made the use of advanced wastewater treatment technologies complicated. Various actors and stakeholders such as utilities, contractors, communities, and citizens' association influenced the adoption of those technologies. They developed and analyzed a conceptual framework for two dimensions, the role played by firm-specific characteristics and the influence of community-level factors. The interviews with the CEOs and top managers of 11 wastewater utilities operating in a region in North-Italy through multiple descriptive case studies were used to investigate these issues. The results suggested that even with an adverse institutional environment, adopting innovation of wastewater utilities could be influenced by the firm-specific resources. On the community-level, the analysis showed that residents and local businesses were able to mobilize resources and apply pressure for driving or hindering the adoption of innovations of water utilities.

Over the last decade, a more integrated, sustainable, and adaptive management approach has been called within the urban water sectors. The slow process of transitioning to sustainability-focused water management was observed. The water sectors consider sector-specific characteristics, and various drivers or constraints. By providing a more holistic view of potential options and transition pathways, business models can be used for change. Muller et al. (2016) studied the concept of business modeling for use in Sustainable Urban Water Management (SUWM). Two cases were studied by a literature-based comparative assessment. They demonstrated the practical relevance of the proposed framework within the urban water sector for understanding enablers and inhibitors of change and identifying strategies for sustainability.

Water infrastructure planning frameworks has been paid little attention to whose interests are served. In reality, the planning process shall be considered by social and political dimensions. Furlong et al. (2016) developed a water infrastructure planning framework for this subject by reviewing the evolution of planning theory in the beginning. A draft framework was developed through consultation with water industry experts and the comparison of existing frameworks. The proposed framework showed the benefits for decision making, cost-sharing, the effects of public and media perceptions, and the impact of government and community preferences. Finally, this framework was recommended for use in both planning and analysis

Sustainable Water Resources Management

Because of the construction of the Three Gorges Dam and other hydropower stations along the upper Yangtze River in China, Poyang Lake suffers from a severe shortage of water. Zhang et al. (2016) proposed a model to study the optimal sustainable growth path for the effects of extractive water use and impoundment activities. They illustrated the mechanisms of the regenerative capacities for water resources on the long-run economic growth path. The results showed some supporting theoretical evidence for restoring regeneration capacities of Poyang Lake by constructing a water conservancy project.

The concept of sustainability has been associated with the environmental, social and economic triple bottom line framework. Borrego-Marin and Riesgo (2016) enlarged sustainability by including the aspects of governance. According to the Water Framework Directive, they analyzed and compared the sustainability of the water plans in the Spanish River basins. Two proposed approaches of multi-criteria decision analysis were used to study the sustainability triple bottom dimensions. Results showed that the important role in plays the most important roles in the whole sustainability (40%) of water basins from the highest to least are the environmental dimension (40%), both economic and social dimensions (25%),governance dimension (11%). Managing water for sustainable use is both a technical and a governance challenge. Knowledge production and sharing for this challenge play a central role. Jacobs et al. (2016) evaluated the decision-making role of scientific information and participatory governance in four basins in four countries. The results show that participatory processes appear to work better in the short-term and easily adjusted decisions such as water-allocation decisions, and do not work so well for longer-term, highstakes decisions such as infrastructure. Another finding shows that the costs of capacity building are not widely recognized for stakeholder engagement in water-management decision processes. Not appreciating the associated costs and complexities regarding infrastructure may cause the lack of successful citizens' engagement of in decisions.

The impacts of integrated water resources management (IWRM) on water resources are considered as key components for environmental sustainability. Istanbul, Turkey is a very large population metropolitan city. Because of a large in-migration, The Istanbul has almost twice the overall population growth rate of the whole Turkey. Leeuwen and Sjerps (2016) studied a baseline assessment of IWRM of Istanbul and a critical review of Istanbul's future challenges. Istanbul is a good example for megacities to the water supply challenges for illegal settlements on watershed that created a threat to scarce water resources. The IWRM review of Istanbul provides confirmation that water supply is one of the top three global risks for both the impact and likelihood which are the conclusions of the World Economic Forum.

The world faces water scarcity and water stress. The water crisis in the Arab region is complex. Environmental ethics can be considered as a tool for sustainable resource management in the region. Using a social code of environmental conduct, Al- Weshah et al. (2016) studied how environmental ethics could best utilize to ensuring sustainability. It discussed new techniques and tools based on decision-making participation of stakeholders.

Water sensitive urban design (WSUD) has become more and more popular in recent years. Simple software tools for evaluating or simulating the effect of WSUD on the local water balance are still needed. Henrichs et al. (2016) developed a software tool that supports planners for optimal WSUD. This software is an easy-to-use planning tool for established measures and land covers. Results show that WSUD is based on climate conditions and the natural water balance, and site-specific.

Decision and policy makers use quantitative indicators as a common means of assessing the complex dimensions of a sustainable freshwater system. Although there is an abundance of indicators in use, end-users have difficulty to identify suitable assessment methods due to considerable variation. Vollmer et al. (2016) reviewed 95 water-related indices and analyzed them. They concluded that rather than only assessing and monitoring existing conditions, indices can be considered as solution-oriented tools for evaluating and identifying scenarios and tradeoffs among services and beneficiaries,.

Sustainability in Water and Wastewater Treatment

Megacities in urban areas face intense water management challenges. These urban areas are influenced by local interactions between people and human-made or natural systems, and distant systems through flows of water, energy, and others. There is a strong need for applying integrated frameworks to analyze systematically urban water dynamics and influencing factors. Yang et al. (2016) applied the framework of environmental and socioeconomic interactions over distances to analyze urban water issues, using Beijing as a demonstration megacity. The Beijing example reveals many gaps in research and management needs.

Environmental scientists and engineers have difficulty for the handling and disposal of sludge for water treatment plant. It is a challenging task for waste sustainability and requires careful consideration. Ahmad et al. (2016) investigated the physicochemical characteristics of the sludge and its toxicity to environment and explored various alternatives of constructive sludge application. Several reuse alternatives have been studied. The study focused on the beneficial reuse in various environmental settings. This may assist in developing suitable sludge management strategies under stringent environmental regulations for sustainable development.

Wastewater treatment plants need to consider sustainability which consumptions of water and energy for treatment and transportation become the important considerations. Resource recovery can result the less water and energy consumptions. So far, the integration of sustainability of wastewater treatment plants and resource recovery has not been fully studied. In the study by Cornejo et al. (2016), life cycle assessment (LCA) was used to evaluate how the implementation scale influences the sustainability of wastewater treatment with the integration of water reuse, energy recovery, and nutrient recycling. The results show that the centralization of wastewater treatment plants with resource recovery has economic benefits. The community scale has the lowest eutrophication potential. In some cases, several factors such as selection of technology, nutrient management, and others may result more sustainability impact than the implementation scale.

Using multiple criteria decision making can be considered as an approach by prioritizing various technologies for solutions in industrial wastewater treatment. Aydiner et al. (2016) used decision making tools to study four innovative systems compared to a traditional system for treatment and utilization of dairy industry wastewater. The analyses were used to select to the alternative preferences classified regarding the environmental, economic, and technical aspects. The results showed that in dairy wastewater treatment, the better treatments for effective industrial water reuse and waste minimization are membrane technologies. Using environmental, economical, and technical approach can achieve more sustainable dairy wastewater management than the current condition.

Water shortage becomes the serious concern and important issue around the world. The emerging integrated membrane bioreactor has shown the advantages over the conventional membrane bioreactor. Neoh, et al. (2016) reviewed the current research for the integrated membrane bioreactor system with other technologies for wastewater treatment. The areas for potential applications of various types of membrane bioreactor are discussed in this review. It provided the uprising wastewater treatment technology by implementing integrated membrane bioreactor. Water and energy have always been very important for the economic and social growth in the world. The supply and use for sustainability must be considered. Le and Nunes (2016) discussed opportunities for membrane technologies in sustainability of water and energy by analyzing their potential applications and current status; providing emerging technologies and reviewing research and development challenges for membrane materials in this field.

In small communities, ecosystem pollution is a great concern due to the lack of or inefficient wastewater treatment coverage. Matamoros, et al. (2016) studied 4 different full-scale wastewater technologies used in northeastern Spain for their seasonal performance on removal efficiency of emerging containments, total suspended solids, chemical oxygen demand, and others. The technologies were two intensive treatment systems (an extended aeration system and a rotating biological contactor) and two extensive treatment systems (a constructed wetland and a waste stabilization pond). All the technologies except the waste stabilization pond system showed seasonal variability in the removal of emerging containments. All the technologies could decrease the aquatic risk, only the waste stabilization pond showed no risk in both seasons.

Wastewater treatment is an important component in the water cycle for water reuse, energy generation, and the recovery of products from waste. The scientific community has paid significant attention to wastewater treatment, especially from a technical point of view. Extensive literature is available on new technologies, processes, and materials to improve wastewater treatment. However, not many studies focused on the development of a performance measurement tool that supports plant managers. Guerrini et al. (2016) addressed this literature gap by developing a reporting tool that integrates technical and cost measures and implements it in a large wastewater utility. The tool successfully identifies cause and effect linkages among key plant performance drivers and supports management in finding activities with poor performance and allows them to delay non-relevant measures of control.

Desalination technologies have evolved and advanced with increasing water demands in recent years. Many reviews have focused on the technical, economical, and environmental and ecological issues of the desalination technologies. They also emphasized the feasibility of desalination industry as an alternative to meet the water demands in water shortage areas. In spite of these efforts, many perceptions about desalination processes impact the applications for potential water supplies. Gude, V. G. (2016) provided an overview of the desalination trends around the world and discussed case studies for desalination, and other factors that influence sustainable desalination and alternatives for desalination. Although some of the facts and recent developments showed that desalination can be affordable and sustainable, more studies of the future development of desalination technologies are still needed.

Sustainability for water and energy

Fournier et al. (2016) studied the usage efficiency of water-energy for the large scale civil infrastructure projects using the reuse of treated municipal wastewater and recharging subsurface groundwater aquifers. A modeling framework is used to explore spatially heterogeneous variables and determine the physical layout of proposed reuse system. This framework is applied to the energy-water usage efficiency of hypothetical reuse systems in five case study regions in California. Findings from these case study analyses suggest that, in certain geographic contexts, the water requirements attributable to the process energy consumption of a reuse system can exceed the volume of water that it is able to recover by as much as an order of magnitude.

The electricity generated in the United States is mainly contributed from the thermoelectric power plants. These plants use a lot of water to cool steam condensation in the power generation cycle. The water constraints for heavily depending on the cooling water can become energy constraints. Competition of water demand creates a need for building a baseline of present water requirements and predicting possible impacts from future water and energy management decisions. DeNooyer et al. (2016) used the Illinois data to analyze the current water demands for power generation by synthesizing a geographic information systems (GIS) model of present and projected water demand for thermoelectric power plants. Two potential future cases are used to evaluate water use implications for a shift in fuel from coal to natural gas, and a shift in cooling technology from open-loop to closed-loop cooling. Their results show that a shift from coal-generated to natural gas-generated electricity could decrease statewide water consumption and withdrawal. A shift from open-loop to closed-loop cooling technologies could decrease withdrawals with the tradeoff of increasing statewide water consumption for power generation.

Energy consumption plays a significant portion of the operation costs for a wastewater treatment plant. Panepinto et al. (2016) proposed a multi-step methodology for evaluating energy consumption of the wastewater treatment facility in Italy. In order to obtain specific electricity consumption values for all the electro-mechanic devices, each phase of the process scheme is taken into account. Data from tele-control system and direct measurements in field are used to evaluate total electric energy demand of the plant. Positive results were verified with the account of large contribution the energy efficiency of the blowers. The whole plant was evaluated for an energy balance and some optimization solutions to decrease the corresponding energy costs were recommended.

In Thailand, the demand of palm oil for food, cosmetics and others have been increasing. This results the rapid expansion of oil palm cultivation nationwide. The concerns on the environmental sustainability of oil palm cultivation have been raised. Silalertruksa et al. (2016) studied the water scarcity footprint of oil palm cultivation in the different regions of Thailand. There is a wide variation of Green House Gas (GHG) emissions and irrigation water required. Oil palm cultivation in the South brings about the lowest water scarcity footprint followed by the East, North, Central and Northeast, respectively. Promotion of oil palm cultivation must thus be based on land and climate suitability considerations along with good practices for productivity improvement. Recommendations have been discussed for enhancing sustainable oil palm cultivation which in turn will improve the competitiveness of the Thai palm oil industry.

Water and energy are the important resources in the world environment and economy. Understanding those nexus can reduce emissions and minimize the consumptions. Wakeel et al. (2016) conducted a literature review of the several fronts to reduce energy consumption in the water sector. These include current condition, gaps of research, factors of dependence, and improvement measures. The review covers the extraction, desalination, pumping, collection, and wastewater treatment stages of the water sector for various countries. Due to old infrastructures and technologies, the results show that water supply and wastewater services are energy intensive. Energy intensities in the water sector vary with technology, geographical distances, and demographic conditions. The methodologies for energy accounting for various water uses are also summarized. Finally, knowledge gaps, challenges and policy implications are identified by synthesizing previous research.

Energy supply and efficient production and use are the important factors for the world healthy economies. The principle of minimizing negative environmental impacts can be used to ensure sustainability, and the supply and use of energy is applied. Regarding this, ensuring cleaner energy is the key for cleaner production to reduce the emissions of greenhouse gases and other pollutants. Yong, et al. (2016) reviewed the main lessons recently learned in the area of more efficient energy use, cleaner fuels and biofuels, cleaner production, CO2 capture, optimization and waste management.

Water Quantity

Bhaskar et al. (2016) monitored base flow pre- and post-development in a developing watershed in Clarksburg, MD between 2004 and 2014. The watershed was widely implemented with infiltration-based practices post-development and the monitoring revealed an increase in base flow relative to pre-development conditions suggesting a shift of evapotranspiration to base flow. Runoff reduction of permeable pavement retrofits in St. Louis were evaluated by comparison of pre- and post-construction monitoring of three sites. The alleys showed different percentages of runoff reduction from different types of pavement, 36, 13, and 46% from permeable concrete, permeable asphalt, and permeable pavers respectively (Alyaseri and Zhou, 2016). The impact of green infrastructure adoption on local hydrology was evaluated for a two-block residential area by using a before-after-control analysis and evaluating peak discharge, total runoff volume and hydrograph lags. It was found that green infrastructure was very effective in substantially reducing stormwater, but design features (e.g. underdrains in rain gardens) were important in determining the level of benefit (Jarden et al., 2016).

Feng et al. (2016) evaluated the potential for green infrastructure to restore pre-development hydrology in a semi-arid urban catchment in Salt Lake City, Utah (USA). Based on modeled results, they found that the water budget of the study catchment was restored by the green infrastructure plan (a combination of green roofs and bioretention areas) to 90%, 90%, and 82% of the predevelopment state in the dry, average, and wet years, respectively. An evaluation of watershed-scale impacts of green stormwater infrastructure was performed for Washington, DC (USA) and Baltimore, MD (USA) and found that, "when controlling for watersheds size and percent impervious surface cover, watersheds with greater amounts of SGI have less flashy hydrology, with 44% lower peak runoff, 26% less frequent runoff events, and 26% less variable runoff (Pennino et al., 2016).

Using EPA SWMM 5 model and residents survey results, the reduction of peak flow and total runoff volume was evaluated for the city of Syracuse, NY (USA). The simulation results indicated that both the "government participation" and "household participation" scenarios, compared to pre-GI-development conditions, would contribute to a modest reduction in stormwater peak flow (> 4 %) and total runoff volume (> 5 %) across the simulated sewersheds(Sun and Hall, 2016). Wright *et al*. (2016) assessed the effectiveness of LID in Lafayette, Indiana (USA) and found, depending on LID practice implemented and adoption level, runoff volume reduction of 10-70% volume could be achieved. Zellner et al.(2016) developed a spatially-explicit process-based model (the Landscape Green Infrastructure Design model, L-GriD) to, "understand how the design of green infrastructure may affect performance at a neighborhood scale, taking into consideration the magnitude of storm events, and the spatial layout of different kinds of land cover."

Rostad et al. (2016) estimated the impact of rain-water harvesting on potable water demand and generation of stormwater runoff across New York City, Philadelphia, Chicago and Seattle (USA). For a typical rainwater harvesting system consisting of a 100 m^2 rooftop connected to a 5 m^3 storage tank at maximum build-out, potable water demand water and runoff were reduced by 65% and 75%, respectively, for all four cities. Using a GIS framework, the impact of green roofs on urban flash floods was simulated using Deakin University's Geelong Waurn Ponds campus (Australia) as a case-study and revealing varying degrees of stormwater mitigation (Liu and Li, 2016). The impact of landscape patterns on peak runoff for areas in Texas (USA) were evaluated finding that, "larger, less fragmented and more connected landscape patterns are likely to mediate the mean annual peak runoff," which has implications for design of green infrastructure and stormwater management (Kim and Park, 2016).

Brown and Borst (2016) assessed the accuracy of several methods for the estimation of runoff from an impervious asphalt contributing to permeable pavement in a parking lot in Edison, NJ. Evaporation from the permeable pavement profile was found to be not insignificant in the calculation of actual runoff and the Soil Conservation Service Curve Number (SCS-CN) method gave estimates of runoff that were 15% less than the average. Feng and Burian (2016) incorporated Penman-Monteith evapotranspiration model into the United States Environmental Protection Agency's storm water management model (SWMM) to improve how ET is calculated in the model and ultimately water budget analyses, ecosystem services assessments, and coupled modeling studies such as with urban climate models.

A water balance based model for green roof runoff, called SWAM, was presented and validated using data collected from green roofs in New York City, NY (USA). Good agreement between modeled results and monitored values was shown using low-cost monitoring techniques (Hakimdavar et al., 2016). Curve numbers and runoff coefficients were developed for green roofs, across various climates, with a stepped approached proposed for the use of curve numbers. For small events (less than 20-30 mm) a CN of 0 was proposed and for large events, a curve number of 84 is proposed (Fassman-Beck et al., 2016). A simple tool for quickly sizing rain gardens using nomographs was presented. The method was applied to an existing raingarden in a sub-humid region of China, and showed that the predicted overflows under large storm events were within 13-50% of the measured volumes (Jia et al., 2016).

Winston et al. (2016) assessed volume reduction and peak flow mitigation for three bioretention cells in clay soils in Northeast Ohio (USA) with internal water storage. Runoff reduction, on average, was 59%, 42% and 36% with the underlying exfiltration rate and the thickness of the IWS layer being the primary determinants of performance (Winston *et al*., 2016). Percent stormwater retention for a green roof in Syracuse, NY (USA) was evaluated over a one year period finding mean percent retention of 98% (SD = 2.7%) over 87 storm events with no difference in retention between growing and non-growing season (Carpenter et al., 2016).

Major urban parks across the world e.g. Central Park in New York City, NY (USA) and Emerald Necklace Park in Boston, MA (USA) were evaluated to explore how urban parks contribute to the improvement of urban hydrological systems (Kusuluoglu and Aytac, 2016). The impact of green infrastructure on subsurface water conditions and hydrologic stability was evaluated in several regions of the Netherlands with the goal of archaeological artifact preservation (Boogaard et al., 2016). An evaluation of river restoration possibilities using expert survey results and ArcGIS analysis for river valley in Tehran (Iran) found that restoring river valley function, including hydrology, is highly dependent on urban green patches and enhancing network connectivity among these patches (Masnavi et al., 2016).

Water Quality

An evaluation of watershed-scale impacts of green stormwater infrastructure was performed for Washington, DC (USA) and Baltimore, MD (USA) showing, "44% less NO3- and 48% less total nitrogen exports compared to watersheds with minimal," green infrastructure (Pennino et al., 2016). A novel methodology for designing treatment trains for stormwater management which minimize cost while considering land usage constraints and targeting pollution reduction. A treatment train in Melbourne (Australia) was used for case study (Jayasooriya et al., 2016).

The effectiveness of bioswales at three commercial and residential site in California (USA) to reduce pesticides and toxicity in surface water was evaluated. Reported findings indicate that bioswales effectively reduced toxicity to amphipods and midges, and that contaminants including suspended solids, metals, hydrocarbons and pesticides were significantly reduced by the bioswales(Anderson et al., 2016). The removal efficiency of particulate and dissolved heavy metals for infiltration trenches, tree box filters, a rain garden and a constructed wetland was evaluated over a four-year period finding good performance in all systems with limited particulate bound removal during large storms (due to low heavy metal concentrations) (Maniquiz-Redillas and Kim, 2016).

Runoff quality (pH, conductivity, and concentrations of dissolved nutrients, base cations, and metals) from a newly constructed green roof in Cincinnati, OH, was analyzed over a two year period (>80 events) and was related to environmental factors. Strong seasonal relationships were observed highlighting the need for, "long-term studies to characterize the complexity of these engineered ecosystems and their responsiveness to environmental variation." (Buffam *et al*., 2016). Runoff quality from a green roof located in Syracuse, NY (USA) was evaluated over a one year period (87 storm events), finding significant differences in nutrient retention by season, particularly higher concentrations of nitrogen and dissolved organic carbon during warm, summer months (Carpenter et al., 2016).

The performance of several commercially available green roof trays were studied by Johnson et al. (2016), finding that dissolved inorganic nitrogen runoff fluxes were, "different among plant species and decreased significantly with increasing plant species richness." The performance of grassed and macrophyte planted bioswales in treating road runoff were evaluated finding that in general macrophytebioswale systems performed between in reducing pollutant concentrations and also had less variability in treatment results (Leroy et al., 2016).

Climate Change

Catalano de Sousa et al. (2016) evaluated the potential climate change impacts on vegetation commonly used in green infrastructure in the Northeast US by assessing stomatal conductance and below-ground biomass under flooding and drought conditions. Results suggest no need for irrigation or potential replacement of plants in GI systems in a changed climate. Bioretention practices were assessed in consideration of future urbanization and climate change. Hydrologic modeling results for 2-year and 10-year design storms indicated that bioretention practices were more sensitive to urbanization than climate change in Singapore (Wang et al., 2016). The optimal placement of green infrastructure to mitigate climate change impacts was evaluated for a watershed in northwest Indiana (USA) using L-THIA-LID 2.1 with consideration for both runoff volume and water quality parameters (Liu et al., 2016b).

Two case-studies, one in Vancouver, Canada and one in London, UK, are evaluated to assess the insurance value of green infrastructure to reduce vulnerability and the costs of adaption in the face of climate and other environmental change (Green et al., 2016b). Life-cycle assessment was used to compare green infrastructure and typical sub-surface systems for stormwater management in Denmark for changing climatic conditions. The study concluded that using an LCA approach is important in the early stages of the planning process and that for the evaluation case, the green infrastructure adaptation plan had significantly lower impacts than the traditional alternative (Brudler et al., 2016).

The use of green infrastructure and development of riparian greenways in Santiago (Chile) were shown to address mitigation and adaptation to climate change including cooling and flood mitigation (Vasquez, 2016). The contribution of green infrastructure to climate change adaption is evaluate for Thessaloniki (Greece) and suggestions given for redesign to offer maximum benefits (Salata and Yiannakou, 2016).

Planning and Ecosystem Service Evaluation

A governance model focused on congruence with distributed green infrastructure practices is presented by Dhakal and Chevalier (2016) along with an evaluation of how five US cities have adjusted governance from centralized structures to decentralized structures recognizing the multitude of stakeholders involved in green infrastructure projects. Adaptive management strategies were used in the implementation of rain gardens in Cleveland, Ohio (USA) and lessons learned from partnerships between scientists and practitioners reported (Chaffin et al., 2016). The use of land banks is offered as an example of governance innovation necessary to support urban green spaces in their role as "social-ecological transformation" agents in post-industrial settings (Green et al., 2016a).

Water governance in Pittsburgh, PA (USA) is explored by Finewood (2016) through consideration of the hydro-social cycle and concluding that green infrastructure approaches may not represent a more democratic process in water management. A public policy framework for green and blue infrastructure was assessed for Tours (France) concluding that the current legal power of municipal tools is not currently suitable for the management of ecological corridors (Debray, 2016).

Key factors for consideration of successful adoption of green infrastructure in the UK including physical barriers, perception/information barriers and organizational barriers were studied (Hoang and Fenner, 2016). Flynn and Davidson (2016) used, "the social-ecological system (SES) framework to build a classification system for identifying significant variables that influence urban stormwater governance decisions related to green infrastructure adoption." Practical guidance for decision makers evaluating the benefits of green infrastructure for coastal communities is offered and presented with three case studies from the US Gulf of Mexico and Belize (Ruckelshaus et al., 2016).

A toolbox of methods for green infrastructure design that account for biodiversity and ecosystem services is presented to aid in making green infrastructure a working concept to support ecosystem service (Snall *et al.*, 2016). A new tool (FRAGSTATS) for green infrastructure planning was introduced that uses remote-sensing, land conversions analysis and landscape ecology-oriented spatial analysis (Lynch, 2016). The development and application of a decision-making process or tool to enhance green infrastructure within spatial plans and guidance was presented and found that game-based approach to GI problem-solving was successful in breaking down professional barriers (Lennon et al., 2016).

Using Philadelphia as a case study, an equity index was developed to identify communities that would most benefit from green infrastructure implementation (Heckert and Rosan, 2016). Romania was used as a case study to evaluate the use of urban green space per capita as a target for sustainability goals. Urban green space per capita was targeted at 26 m^2 per capita, however, was found to be unachievable for all Romania cities, indicating the need for city specific indicators that account for factors like, "density of the built-up space, the proximity to major transport infrastructure, the cities' founding period and the geomorphology criteria." (Badiu et al., 2016) The concept of "biological potential" was introduced by Croeser (2016) as a means to assess the potential for urban areas to be retrofit with green infrastructure. The concept was extended to a case study of the potential of walls in Melbourne (Australia).

The use of ecosystem services as a metric for the planning sustainable cities was evaluated for Stockholm, Sweden. The major finding was that, although ES were recognized as a useful concept and needed for the development of sustainable cities, there were concerns that ES evaluation would, "add further complexity to already strained workloads among planners, policy-makers and urban managers." It was suggested that tools and methods be demonstrated in "high-profile" projects (Anna *et al.*, 2016). Balancing urban greening and development in Germany was the focus of a paper which suggested the need for, "cross-scale, legal-planning development strategy embedded in higher European policies," to effectively manage ecological and social concerns (Artmann, 2016).

Closset-Kopp et al. (2016) present indicators for planning ecological corridors in fragmented landscapes (e.g. cities) using Northern France as a case study. A study was carried out focusing on the ecosystem services associated with green infrastructure potential of areas around the Bartin River in Turkey (Artar *et al*., 2016). A framework for stormwater management focusing on green infrastructure and landscape security patterns on a regional scale was introduced using Shanghai Lingang New City (China) as a case-study (Xu et al., 2016).

The ecosystem services associated with urban gardens were assessed for 27 urban gardens and 201 users in Barcelona (Spain). Findings indicated that cultural ecosystem services were most widely perceived and most highly valued by users, a relevant finding for urban planners (Camps-Calvet et al., 2016). A willingness-to-pay analysis for The Wicker, Sheffield (UK) determined that residents were WTP 2% more in monthly rent or additional mortgage payments to live in locations that have a high quality green infrastructure environment (Mell et al., 2016). Stormwater reduction was cited as the most common motivating factor for green infrastructure adoption for respondents in New Jersey, where green infrastructure continues to gain wider adoption with rain gardens being the most popular practice (Rowe et al., 2016). The value of urban ecosystem services in New York City (USA) was spatially evaluated using different valuation scenarios. Substantial differences in the spatial distribution of priority areas for green infrastructure were found between different valuation scenarios (e.g. stormwater priority, local climate regulation, carbon storage, air pollution removal, and recreational potential) (Kremer et al., 2016).

Life-cycle analysis of traditional stormwater control measures compared to green infrastructure for the upper Midwest US showed that green infrastructure (rain gardens, vegetated swales, porous pavement) did effectively reduce LCA impacts compared with traditional management, but there were not significant differences between green infrastructure technologies (Hengen et al., 2016). A life-cycle analysis comparing a conventional and hybrid system of low-impact development and centralized water systems was performed using TRACI 2.1 for Atlanta, Georgia (USA). Findings suggest that LCA benefits of the hybrid system are diminished with increasing population density but that LID can be an effective means to reduce water usage in some areas (Jeong et al., 2016). A life-cycle framework considering economic, environmental and social factors was developed by Zhan and Chui (2016) and applied to Hong Kong (China). The 30-year economic and environmental benefits were found to be 5.3 billion USD and 1.2 billion USD, respectively.

The potential payback period of LID implementation was assessed for neigborhoods in Lafayette, Indiana (USA) and found that payback (relative to cost per cubic meter runoff reduction and saving from reduced runoff volume) ranged anywhere from less than 3 years to not possible to generate a payback (Wright *et al.*, 2016). A cost-benefit analysis of a typical community in Beijing (China) revealed that stormwater management by green infrastructure has higher construction and maintenance cost, the comprehensive benefits warrant promotion of green infrastructure for sustainable urban stormwater management (Liu et al., 2016a).

The question as to whether vegetated rooftops attract more mosquitoes was assessed by Wong and Jim (2016). By evaluating seven sites on a university campus, they found that considerably more mosquitoes were captured on conventional rooftops than on green roofs, attributable to the ponding of water in depression storage on conventional roofs. The use of green roofs by wild bee species was evaluated by Fischer et al. (2016) in Berlin (Germany), finding that restoration of diverse grasslands positively affected bee species richnesss in urban environments. Cameron and Blanusa (2016) looked at ecosystem service provision of various plant types as a means for supporting the planning and selection of highly functional plant palettes for urban landscapes.

Life Cycle Assessment (LCA) Applications

Sustainable urban water management has become more important in recent years. Tools are needed to study the urban water systems for the environmental performance. Loubet et al. (2016) proposed a model to ensure a good representation of water issues and fulfill life cycle assessment (LCA) requirements. The model calculates life cycle impacts at a monthly temporal resolution for a set of services provided to users, as defined by the scenario. It also provides the ratio of impacts to amount of services provided and useful information for urban water systems diagnosis or comparison of different scenarios. The applicability of the model is demonstrated using a virtual case study based on available life cycle inventory data.

To improve applicability of life cycle assessment (LCA) in supporting direct and robust decision-making, Cai et al. (2016) developed an integrated approach through incorporating operational research and uncertainty analysis methods within a general LCA framework. This approach represented an improvement upon conventional LCA method, as well as water resources allocation. The developed method was then verified in a water-stressed city (i.e., the City of Dalian), northeastern China. The application indicated that the proposed method was effective in generating desired water supply schemes under uncertainties, reflecting the associated life-cycle environmental impacts, and strengthening capabilities of both LCA and operational research methods.

Recent developments for negative effects of pathogens on human health in life cycle assessment (LCA) have focused on integrating results obtained through quantitative microbial risk assessment (QMRA). Harder et al. (2016) studied whether the use of QMRA can be the way for integrating pathogen impact potential in LCA and quantifying how the choice of pathogen impact potential is affected regarding mathematical relationships and model structure. Sewage sludge management was used for the study. The pathogen concentrations in treated sludge reported in the literature was also discussed. The results show that the use of QMRA can be an adequate way of integrating adverse effects of pathogens on human health in LCA. However, LCA may require a different parameterization than an ordinary risk assessment.

High-polluted agro-industrial effluents can be treated by conventional biological processes which can produce biogas and sludge. Advanced biotechnologies are developed to treat these effluents and obtain increased biogas production by the useful energy sources, such as bio-hydrogen and even bio-electricity. Comparing with other renewables, utilization of these clean energies is significantly lower, particularly in developing regions such as Latin-America. Meneses-Jacome et al. (2016) performed the literature review of Latin-American research regarding energy recovery technologies from agro-industrial wastewaters and the sustainable implementation. The need for a more sustainable management of the water-energy nexus in treatment systems is also discussed. LCA and criteria-indicators to achieve sustainability studies are updated and used to prepare a conceptual framework for sustainable practices in this sector.

Sustainability and Asset Management

Operational decision-making has hardly been analyzed for sewer asset management. Riel, et. Al. (2016) studied how decisions for sewer replacement are made and to address the extent complexity of the decision-making environment. The rational and streams model is used to analyze the decision process. Decision-making does not depend on data analysis; but also includes negotiations among infrastructure managers involved.

The impact due to pipe failure can be great. The failure consequences can cause property damage, affect traffic, and contaminate water. Utilities have used linear asset management strategies to reduce pipe failures. Also, many proactive linear asset management technologies have emerged. The question has been raised which pipe asset management strategy is most sustainable. Matthews et al. (2016) has used Envision to evaluate three pipe asset management strategies for sustainability. The strategies include: a reactive run-to-failure before replacement; a preemptive replacement prior to assumed failure condition; and a balanced approach of known active condition assessment. Each approach is determined for its sustainability rating.

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