Evaluation Tools and Models for Sustainable Water Management of Developed Countries: A Review

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ABSTRACT
Sustainable water management (SWM) calls for balancing the financial and social resources needed to support essential water systems with competing demands from the water industry. This review's goal is to evaluate SWM across three domains: urban, agricultural, and natural systems. This chapter explores the following questions: (1) How is SWM defined and evaluated? (2) What are the challenges associated with sustainable development in each sector? (3) What are the areas of greatest potential improvement in urban and agricultural water management systems? And (4) What role does country development status have in SWM practices? Depending on the complexity of the problem and the investigators' resources, the methods for evaluating water management practises range from very simple indicator methods to the integration of several models. The two key findings and recommendations for meeting SWM objectives are: all forms of water must be considered usable, and reusable, water resources; and increasing agricultural crop water production represents the largest opportunity for reducing total water consumption, and will be required to meet global food security needs. The level of regional development should not dictate sustainability objectives, however local infrastructure conditions and financial capabilities should inform the details of water system design and evaluation.

Keywords: Sustainable Water Management; Sustainability Evaluation; Urban Water Systems; Irrigation; Ecosystem Water Requirements.

1. INTRODUCTION

Water is at the foundation of sustainable development as it is the common denominator of all global challenges: energy, food, health, peace and security, and poverty eradication.—UN Water [1]

1.1 Definitions

According to the Brundtland Report [2], sustainable development is generally understood to mean satisfying the requirements of the present generation without compromising the capacity of future generations to satisfy their own needs. "Needs" include the provision of economic, environmental, and ecosystem services as well as cultural objectives like identification and arbitrary values. The sustainability triple bottom line refers to three things taken together. Sustainable development combines maintaining the environment, available resources, and local community with the advancement of the economic and societal objectives.

Sustainable water management (SWM), which addresses concerns related to sustainability, is a crucial part of sustainable development. SWM is defined by Mays [3] as satisfying the present water needs of all water users without compromising the supply for the future. SWM should especially support societal goals and preserve ecological, environmental, and hydrologic integrity [4]. Groundwater management is defined by Alley et al. [5] as the process of managing groundwater while preserving the environment, the economy, and society. A more holistic objective is provided in Agenda 21 [6] which ensures that "adequate supplies of water of good quality are maintained for the entire population of the planet, while preserving the hydrological, biological and chemical functions of ecosystems, adapting human activities within the capacity limits of nature and to combat vectors of water-related diseases."

Adoption of definitions of SWM is hampered by the language's pervasive subjectivity and lack of specificity. Most definitions just provide a general understanding of the industries or settings to take into account. Most SWM definitions use terminology that is normative and frequently qualitative. According to the definition of sustainability given by [7] "the design of human and industrial systems to ensure that humankind's use of natural resources and cycles does not lead to diminished quality of life due either to losses in future economic opportunities, or to adverse impacts on social conditions, human health, and the environment," This definition uses "diminished quality of…" and "adverse impacts on…" to describe thresholds of sustainable system effects, which are difficult to interpret for management purposes. With respect to sustainable urban water management in Agenda 21 from the United Nations, Larsen & Gujer [8] assert that no concept proposed is applicable in practice. The normative guidance of most sustainability definitions is especially problematic for policy makers and water managers who are motivated to adopt sustainable practices, but have little tangible support.

1.2 Integration of Sustainable Development and Sustainable Water Management

Due to the need for water for growth, sustainable development and SWM are inextricably linked [9,10]. Since water is a basic necessity for human life and wellbeing, proper water management is a way to increase food production, decrease poverty, and prevent diseases associated with unclean water. SWM entails dividing up water among users and purposes that are in competition. Similar to Maslow's hierarchy of requirements for humans, this allocation can be seen as a hierarchy (Table 1) [11]. The concept contends that before effort can be devoted to meeting higher wants, the basic biological needs must be satisfied. "Safety" is the second level of Maslow's hierarchy, which refers to localised agricultural production and home water security. In this hierarchy, "social" and "esteem," the third and fourth categories of demands, respectively, stand in for greater community water services and an emphasis on upkeep, fairness, and responsibility. Levels 1 through 4 of the two hierarchies are similar, while level 5 appears to be where they part ways. Resource sustainability, which emphasises an outward-looking perspective that includes the fulfilment of other users both now and in the future, contrasts with Maslow's inward-looking "self-fulfillment." The promotion of SWM, the fifth and final need, while still focusing on meeting their fundamental requirements, presents the biggest difficulty for developing nations.

Table 1: Comparison of Maslow’s hierarchy of human needs and the hierarchy of water management needs.

Level	Maslow’s Hierarchy of Human Needs	Hierarchy of Water Management Needs
5	Self-fulfillment	Water resource sustainability
4	Esteem (status, recognition)	National water projects (supply, remediation, public awareness)
3	Social (family, community)	Regional water projects (supply, treatment plants)
2	Safety (security, stability, law, order)	Local development (agriculture, domestic water, water quality standards)
1	Physiological for survival (Air, water, food, shelter, procreation)	Biophysical individual needs (water for survival)

This chapter explores urban, agricultural, and natural water system management in developing and developed nations. We aim to address the following questions: (1) How is SWM defined and evaluated? What are the challenges associated with sustainable development in each sector? (3) What are the areas of greatest potential improvement in urban and agricultural systems? And (4) What role does country development status have in SWM? The goal of this study is to conceptualise the conversation surrounding what comprises SWM practises according to three sectors: urban, agricultural, and natural systems, rather than giving extensive discussion on all facets of water management. Over 80% of all human water use worldwide is for municipal and agricultural purposes, and this percentage is even greater in many developing countries [12]. By 2050, it is anticipated that there will be 1 to 3.1 billion people who experience seasonal water shortages and 150 million people (about 2000) who experience perpetual water shortages in metropolitan areas [13].
70% of all water used globally is for agricultural purposes, and in some poor countries, that percentage might reach 90%. A crucial component of sustainable urban and agricultural management strategies is the management of water in natural systems. Although they may not account for the majority of water usage in a particular location or nation, these three sectors account for the majority of water use globally (e.g., Canada, Russia, and the United Kingdom). Therefore, a more thorough study of SWM at the regional level should be carried out to give the most pertinent data for management and policy objectives.

Table 2: Primary sustainable water management objectives

Sector	Developing Areas	Developed Areas
Urban	Equitable delivery	Supporting demand
	Reliability	Infrastructure longevity
	System flexibility with growth	Recycling and reuse
		Environmental protection
Agriculture	Food security	Crop water productivity
	Expansion of irrigated area	Environmental protection
	Supplemental irrigation	Resource conservation
	Crop water productivity	
Ecosystem	Protection of valued ecosystem services	Protection and/or restoration of natural functions within development constraints

Table 3: Developing country challenges and solutions for sustainabl water management in urban, agricultural, and natural systems

Sector	Challenges	Examples +

Urban	Intermittent operation	India [14], Ethiopia [15]
	Lost or stolen water	Palestine [16]
	Rapid urban growth	China [17]
	Political conflict	*Mid East* [16,18,19]
Agriculture	Irrigation infrastructure cost	*Sub-Saharan Africa* [20]
	Subsidies promoting irresponsible use	India [21]
	Low water use efficiency	*N Africa* [22]; China, Pakistan [23]
Ecosystem	Economic development priorities	India [24]
Sector	**Solutions**	**Examples**
Urban	Institutional improvements	Algeria [25]; Palestine [26]
	Low-tech water capture and treatment *	Greece [27]
	Graywater reuse *	Jordan [28]
	Cooperation, sharing riparian rights	*Mid East* [29]; *World* [30]
	Stakeholder engagement	Mexico [31]; *World* [32]
Agriculture	Optimize water productivity *	*World* [33,34]
	Improve subsidy/pricing structure	India [35]; *Mid East* [36]; *World* [37]
	Supplemental irrigation with rainwater harvesting	*Sub-Saharan Africa* [38,39]; Burkina Faso [40]; *Drylands* [41]
Ecosystem	Communication of ecosystem service value	*Africa* [42,43]; Ethiopia [44]

Notes: + Regions and non-country area descriptions are in *italics*; * Topics covered in the discussion.

Table 4: Developed country challenges and solutions for sustainable water management in urban, agricultural, and natural systems.

Sector	**Challenges**	**Examples +**
Urban	Demand management	Australia [45]; USA [46]
	Cost of adopting new technology	*World* [47]
Agriculture	Over-allocation of water resources	S Africa [48]
	Cost of new technology *vs.* low cost of water	USA [49,50]
Ecosystem	Development priorities	*World* [51]
Sector	**Solutions**	**Examples**
Urban	Conservation education	S Africa [52]; Australia [53]
	Water reuse and recycling *	*World* [54]; UK [55]
	Stormwater management, green infrastructure *	UK [56]; Denmark [57]
Agriculture	Improve water allocation, irrigation management	Greece [58]; Spain [59]
	Affordable precision agriculture methods *	USA [49]
Ecosystem	Identification and protection of most valuable resources	USA [60]
	Definition of a degradation tolerance level	*World* [61]

Notes: + Regions and non-country area descriptions are in *italics*; * Topics covered in the discussion.

2. EVALUATION TOOLS AND MODELS

Sustainable systems are especially apt to compare favorably with conventional systems when the comparison includes a full cost accounting of the environmental and public health harms and benefits of each system.—Horrigan et al. [62]

Real costs, potential costs, and competing requirements between and within water use sectors must all be taken into account when evaluating SWM. These can occasionally include nebulous political and socioeconomic elements that are difficult to translate into the quantitative values required for planning, decision-making, and meticulous monitoring and assessment. A variety of evaluation models are available, ranging from general indices that are used to compare management practises across various agencies and environments to site-specific modelling analyses that allow individual managers and governments to judge whether or not sustainable practises are being adopted [63].

The evaluation's inputs should be quantitative, distinct from one another, clear, and representative. Assessment of conditions and comparison of management solutions are made possible by quantitative evaluations. Numerous tools try to assess the system's environmental, social, and economic facets in accordance with the definitions for sustainable development [64,65]. Although many of these techniques quantify environmental impact and resource use, there are still no reliable quantitative ways to assess social-cultural criteria and the linked consequences of social, biological, and physical components of complex systems [66,67].

Evaluation models must take into account the time- and place-dependent sustainability requirements in addition to having a quantitative framework that spans a complex system. Time is important for both the effects on the environment that follow a certain activity or management approach. The resources that are presumptively available for a specific site are determined by the spatial scale of evaluation, which might range from a home to a town to a watershed to a nation to a multinational region.

The examination of current and projected development will be influenced by the geographic scope of the area, including the quantity of water resources available and competing uses. When determining how a policy will develop over time or when arguing for a particular policy change, it is very useful to take into account local conditions and views in the evaluation approach [25].

SWM can be evaluated using three main techniques: indicators and indices, product-related assessments, and integrated assessments [64]. Information should be clarified, quantified, and communicated using water indicators and indices [68]. Model-specific classification, weighting, and index aggregation methods make the processes relatively arbitrary [68]. The benefit of the indicator method, however, is a straightforward numerical output that allows for case-to-case comparison. The Water Poverty Index [69], Canadian Water Sustainability Index [70], Environmental Performance Index [71], and Watershed Sustainability Index [72] are common indices that deal with water in sustainable development. Water infrastructure, environmental quality, economics and finance, institutions and society, human health, and technology are typical indicators of water management [4]. Accessibility of data, institutional plans to settle water disputes, and democratic water-related decision-making are additional indices that particularly address some of the socio-economic problems previously discussed [3].

Life cycle assessments (LCAs), also known as product-related evaluations, can provide details about the energy, water, and land needs of a physical system or supply chain. The LCA framework can be used to compile a list of sustainability metrics for a water system's whole supply chain. Examples that transform biophysical assets into progress assessments include the Ecological Footprint [73] and its hydrologic counterpart, the Water Footprint [74]. These instruments are resource accounting techniques that allow for integrated quantitative evaluations of land and water resources in terms of present and future demand, as well as regenerative likelihood at national and international dimensions.

Integrated assessments are often comprehensive evaluations carried out with the aid of system dynamics models, risk analysis, cost-benefit analysis, and effect evaluations. In addition to offering a systems perspective, integrated assessments frequently include more reliable quantification than the indicator technique by itself. Information theory can be used to examine the robustness of human systems and how well they utilise resources [75]. To track the acceptance, use, and economics of water systems, a framework based on viability loops can be utilised in conjunction with a systems dynamics modelling approach [76]. When evaluating potential options for sustainable development, Chung and Lee [77] show the value of connecting a hydrologic model and a multi-criteria decision model (MCDM). A Monte Carlo method can be used with several integrated assessment techniques to test for sensitivity and uncertainty.

In addition to the three standard evaluation methods, comparing extraction to the aquifer safe yield is another common method for evaluating groundwater use. Groundwater recharge alone has historically been the only basis for sustainable groundwater extraction, which oversimplified subsurface processes. Early descriptions of safe yield forbade pumping that was "hazardous" [78] or resulted in a "undesirable effect" [79], such as sharp drops in groundwater levels. Safe yield's worth and viability have both been questioned in more recent studies [80–82]. Groundwater development sustainability assessments take into consideration both natural groundwater recharge rates and capture, which includes induced recharge and reductions in natural outflow [5, 83, 84]. Our assessments and projections of the sustainability of groundwater usage are getting better because to developments in numerical and statistical models.

Water users and managers have access to a wide range of instruments to evaluate the sustainability of water consumption and allocation in particular water systems at various scales thanks to the variety of evaluation methodologies discussed above. These instruments demonstrate how difficult it is to assess sustainability in both the physical and social spheres. Different water quantity sustainability evaluation techniques may be chosen depending on local variables, data availability, and sociopolitical goals. This is particularly relevant for setting estimates of thresholds for sustainable use and allocation. Future work will improve evaluation frameworks in terms of measuring and assessing SWM including spatial and temporal efficiency, supply longevity, and equitable distribution.

3. Sector Reviews

3.1 Developing Countries: Practices, Challenges, and Solutions

3.1.1 Urban Water Development

One of the most essential conditions for a healthy and productive development is having access to drinkable water. Water and socioeconomic development are inextricably linked; they can either foster destructive development practises or reinforce them [85]. Water that is dependable, equitable, and conveniently available is essential for sustainable development in metropolitan settings (Table 2). In developing countries, providing water to the fast expanding urban populations is a challenging logistical and financial issue. This is further worse in locations where urban growth is mostly unplanned and informal because it is difficult to forecast demand and track consumption in these areas.

Indicator approaches are frequently employed to assess urban water management. The UN Centre for Human Settlements and the UN Environmental Program are actively working to quantify the linkages between urban water management and environmental sustainability, which is necessary for the development of effective indicator approaches. Urban water systems monitoring and assessment in developing countries will help to improve the current situation and guide future growth. Technical, social/environmental, economical, and institutional factors were used in one evaluation to evaluate 25 indicators [86]. They discovered that while financial and institutional factors are critical, technical criteria (design flow and the system's functionality) and social criteria (status of usage, equity, decision-making in operations and maintenance) are more important for maintaining a water system.

Urban water system sustainability is hampered by issues with infrastructure, socioeconomic situations, and physical resources (Table 3). While water challenged areas aim for fair water distribution among consumers, water wealthy areas optimise water distribution systems to satisfy a specific minimum pressure. To avoid pressure issues and distribution disparities in the latter scenario, distribution systems should be constructed with the expectation of intermittent operation rather than assuming constant supply [14]. In order to meet the demands brought on by population expansion, infrastructure design and water supply issues must be overcome in both water-rich and water-poor locations [17]. Leaking pipes and "stolen" water in areas with a lack of water are examples of infrastructure and operation issues. Water distribution is impacted by problems with construction and material quality, electrical availability, and operation and maintenance. In rural Sub-Saharan areas, 30% of water supply systems are currently non-operational [15]. Infrastructure concerns are a challenge, but their root causes could be socio-institutional issues with accountability, expertise, and coordination [87].

SWM is significantly hampered by regional conflict, particularly in nations with varying levels of development. Two factions of a local community are shown in Melloul and Collin's [11] example to be in various phases of the Water Management Hierarchy of Needs (Table 1). Conflicts over resource allocation and development plans resulted from these discrepancies. Political strife frequently causes more water stress, and vice versa. Numerous UN initiatives, such as transboundary integrated water resources management and urban water supply, are involved in the assessment and management of water resources [88]. Recent analyses of competition and cooperation in transboundary water management clearly favour cooperation among riparian neighbours over conflict [29,30]. Participatory planning and water collection and reuse are increasingly being used as sustainability solutions.

Training of staff members, monitoring, adherence to health and safety rules, and user interaction are all necessary for water system maintenance [25]. Sustainable water utilities should consult the community they serve and draw on traditional management techniques and local understanding of water resources [89]. Political strife frequently causes more water stress, and vice versa. Numerous UN initiatives, such as transboundary integrated water resources management and urban water supply, are involved in the assessment and management of water resources [88]. Recent analyses of competition and cooperation in transboundary water management clearly favour cooperation among riparian neighbours over conflict [29,30]. Participatory planning and water collection and reuse are increasingly being used as sustainability solutions.

Training of staff members, monitoring, adherence to health and safety rules, and user interaction are all necessary for water system maintenance [25]. Sustainable water utilities should consult the community they serve and draw on traditional management techniques and local understanding of water resources [89]. Reuse of graywater in urban areas is becoming more common in water stressed, developing regions [28]. Decentralized systems are recommended at the household or neighborhood scale for producing recycled water for gardening or domestic reuse.

3.1.2 Agricultural Water Development

A key component of sustainable human development is food production. In both rainfed and irrigated agriculture, sustainable agricultural water management goals include achieving food security and maximising food water productivity (Table 2). The majority of the world's population growth is taking place in developing nations, some of which have significant rainfed agriculture dependence. To feed the expanding population, rainfed agriculture must therefore grow and/or have increasing production [95]. The dangers associated with entirely rain-fed agriculture are decreased by irrigation, which acts as a water supply buffer during dry spells. Despite the fact that irrigation during the past few decades significantly increased productivity in China and India, it also caused a greater reliance on non-renewable water sources in many areas.

Future development will be able to avoid these negative effects with the help of quantification of the effects of agricultural practises on water resources. With the aid of case studies for China and Tunisia, Pereira et al. [34] provide an indicator approach for assessing agricultural management strategies. They take crop production economics and water reuse into account in their methodology. Agricultural plans were defined by Dixon and Wood [44] using the optimization of social, environmental, and economic advantages. While not cultivating wild regions was environmentally responsible, it did little to advance human development.

The mixed-use strategy suggested by the optimization method called for maintaining some of the land in its natural state while cultivating other portions. Optimizing agricultural growth and environmental water resources is unusual, notwithstanding the success that has been shown.

Few countries that participated in the Green Revolution gave boosting yields and achieving food security targets priority above sustainable agricultural water usage. Because of this, the Green Revolution had many unforeseen environmental effects in addition to increasing crop yields by more than doubling, which contributed to better food security, lower food prices, and better social and economic conditions [96]. Government water and energy subsidies have increased the use of irrigation and crop production, but the cheap costs have minimal effect on farmers' decisions to practise water conservation and adopt more effective irrigation techniques. More than 100% of the renewable water resources are annually consumed for irrigation in several agricultural regions [97]. These regions must assess alterative irrigation support policies and agricultural water management strategies in order to sustain production in the future [21].

Solutions include using additional irrigation to increase water productivity and decrease risk in crops grown using rainwater (Table 3). A switch from the Green Revolution to the Blue Revolution, where productivity is determined by agricultural yield per unit of water, is proposed by Postel [33]. Irrigation systems across a large portion of the developing world are less than 50% effective. It takes advancements in technical, managerial, institutional, and agronomic practises to increase irrigation productivity. The ability to feed expanding populations in rainfed agricultural regions will depend on advances in rainwater retention, the choice of drought-resistant crops, and alternative tillage techniques [22]. Rainfed crop yields can be more than doubled by using soil fertility management and rainwater gathering for additional irrigation to lessen the effects of dry spells [38,40]. Though the practice is not broadly used, there is widespread potential for water harvesting for supplemental irrigation in many rainfed agricultural regions [39,98].

3.1.3 Environmental Protection

To safeguard ecosystem services, environmental sustainability assessment must be done in tandem with development planning (Table 2). An strategy that is frequently used to assess effects on both the natural and human environments is integrated modelling. In order to evaluate the effects of rainwater collection and storage on downstream hydrological and environmental conditions, for instance, integrated modelling might be utilised [99]. By using this strategy, water stakeholders upstream and downstream can have fewer disagreements while still maintaining environmental flow needs. In order to assess the conservation of land, water, and forest resources, a case study in northern India provides an example of a progressive water resource development strategy [24]. Their suggested strategy takes user needs, socioeconomic possibilities, and ecological sustainability into account. Assuring revenue production in areas where job possibilities may be impacted by land use change is a crucial and rare part of their suggested plan. This is crucial because there is a focus on protecting and restoring the land in a region where 77% of people depend on agriculture for a living, which is common in rural developing countries.

Communicating the economic value of natural resources is an excellent way to promote conservation and land protection [42,44], enabling a community to choose the best development option (Table 3). Sustainable resource use and environmental conservation are inherently given top importance by communities whose livelihoods rely substantially on the natural world [43]. Assessing whether a usage scenario safeguarding water resources is most advantageous for stakeholders is made simple by quantifying ecological value.

With the exception of the research mentioned above, the Millennium Ecosystem Assessment report [10], and the biannual publication of the Environmental Performance Index [71], relatively few studies investigate sustainable human development and water in the natural environment in developing nations. According to the Water Management Hierarchy (Table 1), addressing current fundamental requirements should come before making plans for a sustainable future in many developing regions. Protection of the environment is typically not included in policy since it is seen as being anti-development. The Southern African Development Community has accepted the core tenet that "measures to reduce poverty should not lead to additional deterioration of water resources or ecological functions and services" in order to lessen the dangers associated with this policy omission. They want to integrate sustainability standards into water resource management and policy, particularly in underdeveloped countries.

3.2 Developed Countries: Practices, Challenges, and Solutions

3.2.1 Urban Water Development

Every human being has a right to clean water. For urban areas, our vision is water management where water and its constituents can be safely used, reused and returned to nature.—Hellström et al. [67]

Meeting needs for drinking water, drainage, urban agriculture, and recreation are among the main purposes of managing urban water resources. Sustainable development is essential to addressing these needs while safeguarding natural resources and human health, particularly in areas with limited water resources [100]. Water demand management and the expense of implementing innovative, sustainable solutions are challenges (Table 4).

Similar to research conducted in developing countries, indicator approaches were most frequently used to assess sustainable urban water management. Five categories of sustainability criteria are used in Sweden's Sustainable Urban Water Management Program. The criteria include: nontoxic environment, health and hygiene, human resources, natural resources, financial resources, functionally robust and flexible, adaptable to local conditions, and easy to understand to encourage responsible user behaviour [67]. The assessment framework's modular design enables it to be applied to the evaluation of cities, buildings, and situations. With 51 and 40 variables, respectively, the Sustainable Index for Taipei and Sustainable Seattle are two cities that have created their own methods for evaluating sustainability. Unfortunately, development frequently results in some kind of resource or environmental deterioration. In these circumstances, "sustainable" behaviours could be seen as having the least negative effects on the environment, the economy, and society. For instance, a suggested water strategy would employ a hierarchical tree of environmental values to target harm to the least valuable resource in order to account for future growth in the water-scarce western United States [60].

Water demand management is important in affluent nations when water usage far outweighs dietary needs. Resources, population expansion, and climate change all influence the need for conservation and demand management. Education and awareness are essential for attaining conservation goals, in addition to technological innovation and financial incentives. One case study came to the conclusion that user education and awareness should receive 50% of time and resources [52].

In their study of sustainable urban water management techniques, Marlow et al. [47] also mention potential obstacles, such as the uncertainty and difficulties associated with adopting innovative technology, financial considerations, and institutional prejudice or advocacy. As more cities implement sustainable practises, it becomes increasingly important to share experiences and outcomes to increase acceptance of innovative systems, which may involve experimentation and carry inherent risk. Water rates that are reflective of its full value may be able to offset the expense of infrastructure and technological advancements.

Green infrastructure strategies and wider adoption of water reuse are potential future solutions for sustainable urban water management. Two categories of strategies can be used to improve sustainable water reuse: (1) Substitution (such as rainwater collection and graywater reuse) and (2) Regeneration (such as potable reuse and wastewater reuse) [54]. The development of effective reuse programmes depends on public understanding of treatment procedures and cooperation regarding how treated water can be used safely [53]. Stormwater runoff should be considered as a possible water source rather than water that needs to be treated and sent elsewhere, in addition to treating and reusing wastewater [91]. Ellis (56), a proponent of a broader green infrastructure framework, calls for the installation of green roofs, the disconnection of downspouts, and a canopy cover of 25% to 30% in riparian corridors. These more comprehensive sustainability techniques can enhance urban water management while lowering energy use and enhancing regional ecological services.

3.2.2 Agricultural Water Development

Seventy percent of the water used globally is for agricultural purposes. In industrialised locations, irrigation is widely used because it supports higher crop yields while posing less risks [101]. Numerous facets of industrial agriculture in the first world are unsustainable, much like in underdeveloped areas where irrigation is taking place [62]. The unavoidable negative effects on the environment must be taken into consideration when evaluating water management in agricultural development [80,102]. Determining the level of environmental deterioration that people are willing to accept is necessary for evaluating the sustainability of irrigation practises. It is important to take into account off-farm (or downstream) effects when developing metrics for assessing irrigation systems and on-farm water utilisation procedures. SWAGMAN is a tool that combines economic, environmental, agricultural, and hydrologic models [103]. The SWAGMAN model aids in identifying crop varieties and irrigation techniques that raise agricultural output while enhancing the environment in comparison to business as usual. Sustainable irrigation techniques are always site-specific and influenced by the local climate, terrain, soil, and water supply. For instance, different techniques will be required in places with short water tables compared to those with deep water tables. Water logging and soil salinization may be the main issues with the former, whilst energy costs and groundwater depletion are problems with the latter.

Agriculture will always have a negative influence on the environment, although this impact can be reduced by using water and nutrients more effectively [104]. The agricultural sector presents a clear opportunity to increase water productivity. Improving water allocation and increasing application efficiency are two key topics (Table 4). Given the local temperature and growing conditions, it is necessary to choose crops that use less irrigation per unit of yield in order to improve allocation. For instance, cutting back on beef production, which uses 100 times as much water as producing the same amount of protein from cereals [105], would increase water productivity. A deeper comprehension of the biological, biogeochemical, and ecological processes operating in agricultural contexts is necessary for significant increases in crop water productivity. No-till farming, drip irrigation, or other effective irrigation techniques, as well as soil tensiometers or moisture sensors, are examples of improved farm management practises. Many farms in wealthy countries can afford to employ irrigation, but only 10% of farmers in the Western United States use soil monitoring technologies to better time the delivery of irrigation based on actual circumstances and plant needs [49]. The low rate of adoption of precision agricultural technologies is proof of the financial and practical challenges farmers confront. The cost of pumping water from deep aquifers would rise when aquifers are depleted, though, which might make conservation technology more viable. The answer calls for effective irrigation technology that are economically advantageous to the costs associated with present water use.

3.2.3 Environmental Protection

Development needs must be balanced with environmental preservation or restoration in water management (Table 2). In both applied and academic literatures, numerous techniques for ecosystem or environmental evaluation have been created (e.g., [105–107]). Stream discharge, groundwater elevation, lake stage, and rates of flow between surface, soil, and groundwater are examples of typical water-related evaluation criteria. For defining sustainable hydrologic behaviour, some of these criteria have simple thresholds, while others have more complex dynamic requirements. For determining the viability of riverine systems in developed watersheds, numerous models can be applied. A single minimum flow threshold is insufficient, and hence the Ecological Limits of Hydrologic Alteration (ELOHA) framework is predicated on the requirement of natural flow variance [108]. Look-up tables and hydrologic modelling can be used to describe the amount of flow or the flow regime in a river [109]. Statistical techniques can be used to compare the current flow frequency distributions to a natural reference in an effort to simulate natural flow variability on a controlled river [110].

To aid prioritise protection and management, several integrated models seek to determine the worth and risk of the natural water system under various scenarios of human development (Table 4). The effects of population expansion and development can be modelled and utilised to inform water management methods given the natural or intended streamflow regime [111]. Results can be used to pinpoint areas where water and growth management methods are most necessary and beneficial when applied across various watersheds. Alternately, modelling might spot conflicts between ecosystem needs and human requirements, which are subsequently used to create and evaluate fresh management approaches [107]. To take into consideration seasonal and long-term patterns in water supply and demand, the timing and frequency of incompatibilities must be evaluated using both within-year and among multiple year studies.

Setting a tolerance limit or an acceptable course of action is necessary for defining sustainability because urban and agricultural expansion will have an impact on environmental systems. Chapin et al. [61] suggest an approach to ecosystem stewardship that maintains a trajectory in order to sustain social-ecological systems and ecosystem services rather than defining a fixed objective. The trajectory may shift as conditions change over time, and when this happens, steps should be made to correct the unwanted trajectory. This method's temporal fluctuation may make it more challenging to define, but its adaptability is important for addressing population increase and climate change.

4. DISCUSSION

4.1 Areas of Greatest Improvement in Urban and Agricultural Systems

4.1.1 Urban Systems: All Water is a (Re) Usable Resource

Meeting the challenges of water resources sustainability increasingly involves … applying innovative approaches to conjunctive use of groundwater, surface water, artificial recharge, and water reuse. —Alley and Leake [80]

Water must be viewed as a resource that can be used and reused in all of its states and forms in order to manage water resources sustainably. In areas where there is a water shortage or where one is anticipated as a result of climate change or population growth, it is particularly important to increase the use efficiency, capture, and reuse of these non-traditional water resources. Water scarcity can be solved in large part by treating wastewater [16]. Water collection and reuse are more crucial in areas with rising water stress as climate change makes arid regions dryer [112,113].

When considering all water as a resource, it's important to keep in mind two things: first, not all applications call for water of the same quality, and second, not all "used" water needs to be treated in the same way before it can be put to use again. Treatment of the combined water stream both before and after requires energy and work that is not essential [91]. Water must be priced reasonably in order to encourage a selective system of treatment and reuse. To take into account its competing applications, water must be viewed as an economic good [85], with price variations based on quality and availability. The value of water should be comparable to the expense of purifying source water to required standards in order to promote treatment and reuse.

Both growing and developed areas underutilize green infrastructure and stormwater capture. It is possible to collect and store extra water during heavy downpours for use later [91]. The scale of water capture and distribution can range from household to neighbourhood to city, depending on the level of existing infrastructure and water application needs. Small-scale capture at the home level using storage tanks or infiltration ponds with hand pumps for recovery is advised in many developing locations [114]. Water stress will be considerably lessened through increased capture and use of all available water resources, particularly during dry seasons and times of drought.

4.1.2 Agricultural Systems: Crop Water Productivity

Because agriculture accounts for the majority of water usage, increases in crop water productivity can lead to correspondingly significant decreases in water use. There is almost always room for improvement, with water use efficiency varying between 10% and 30% for agriculture that is rainfed and between 40% and 95% for agriculture that is irrigated [22,115,116]. Supplementing crops grown with rainwater, planning irrigation, and using effective irrigation techniques are all strategies for better on-farm agricultural water management [117]. By increasing food production in areas with high water productivity and exporting to less productive areas, agricultural water usage efficiency can be increased on a national or international level [118]. Subsidies for irrigation (or electricity) should be directed toward areas with reliable water supplies, or incentives for high-efficiency irrigation systems and low-water-use crops should be combined. Irrigation reliability is predicted to decrease from 0.79 (out of 1.0) in 2005 to 0.71 in 2025 as water demands rise in the developing countries [119]. Enhancing productivity (and reducing total extraction) enables production to go on

longer into the future in locations where groundwater use is unsustainable [120].
In comparison to over-irrigation, the use of technology to guide irrigation schedule can reduce water use and boost agricultural yields [121]. Depending on the method and region, different benefits are anticipated from scheduling irrigation. The use of soil moisture sensors and the incorporation of weather forecast information are techniques for scheduling irrigation. Tensiometers, which measure soil moisture, can be used to compare soil moisture conditions to plant moisture needs. Water savings in sensor-informed agriculture can be as high as 50% [122]. By integrating irrigation planning with farm management practises including mulching, lowering soil hydrophobicity, and using wastewater, crop water production can be further increased [123]. Cost of the instruments is the main hurdle in both developing and rich countries. The technology must be created within the means of the intended farmers, or it should receive government funding.
Increases in water use efficiency may enable farmers to irrigate additional land in areas where water rather than land is the production's limiting element. Although it may be argued that this is not a SWM solution because it does not cut down on the overall amount of water utilised for irrigation [124], it does improve the region's agricultural water productivity. In cases were over-irrigation results in runoff and water supply for downstream users, irrigation reduction may in fact reduce water availability to these users, and should be considered in the overall management strategy [125].

4.2 Relevance of Country Development Status

The objectives, difficulties, and solutions for emerging and developed nation SWM are highlighted in this study in terms of both their parallels and differences (Table 2, Tables 3 and 4). Not the definition of sustainability, but rather the context and stage of development, determine the variances. The model chosen for SWM evaluation often differs to account for local economic and infrastructure circumstances while still upholding the goals of sustainable development.
The goal for urban water systems in developed and emerging regions is an equitable and consistent supply. Worldwide issues include infrastructure deterioration and water stress. Developing countries could also encounter issues with sporadic electricity, unequal access to water distribution, or inadequate built infrastructureIn fact, although affluent countries may prioritise water reuse and system lifetime, SWM in developing countries places a greater emphasis on ensuring an equal and reliable water supply (Table 2). Additionally, a lot of urbanised areas now try to create water systems that resemble natural ecosystems [75]. In established areas, the examination of the water system may also contain a demand management component. The Islamic Network on Water Resources Development and Management [16] estimates that more than half of the Middle Eastern population does not currently receive the recommended amount of water, hence this indicator is meaningless in those areas.
Whether a farm is rainfed or irrigated, and what technology and information the farmer has access to, are the factors that evaluation models and opportunities in agriculture are most sensitive to. Growing crop production and distributing water fairly are essential in emerging nations. However, boosting production at the expense of natural resources is not a sustainable solution, as we have learnt from the Green Revolution in South Asia. Supplemental irrigation during crucial growth phases and on-farm management strategies that increase soil moisture holding capacity are effective ways to increase yields in rainfed agriculture. Increasing resource usage efficiency should be a top concern in developed countries with high levels of food security. The answer must include transitioning to more effective irrigation systems as well as the use of soil and plant sensors to guide irrigation scheduling.
Case studies and models from developed regions, where water management demands have been satisfied and sustainability is becoming a top focus, predominate in the literature on environmental water management. Environmental goals are included in both urban and agricultural development, as is shown (Table 2). On the other hand, in developing areas, there are two opposing sides that express the goals for environmental water management. The first claims that environmental sustainability is not a priority until individual and community water requirements are fulfilled and follows the hierarchy of water management needs (Table 1) in that regard. Sustainable development "is only conceivable in the absence of extreme poverty," according to Larsen and Gujer [8]. The preservation of biological variety and other ecosystem needs won't be prioritised in areas with a shortage of clean drinking water. According to this logic, developing nation policy typically does not include real environmental protection because it is viewed as being anti-developmental.

Allowing resources that will eventually be needed for a population to continue growing to be damaged is irresponsible. The second viewpoint, which is shared by communities who rely largely on the environment for their survival, places a higher priority on responsible resource use and environmental preservation regardless of a country's level of economic growth. In terms of environmental sustainability, one progressive organisation is the Southern African Development Community. They contend that improving environmental health and services does not have to come at the expense of reducing poverty. This viewpoint will expand as more effective documentation of environmental protection, economic, and social progress is produced. While SWM is intended for all locations, actual implementation may differ depending on the region's terrain and economic resources.

4.3 Limitations

(2) The following are some of the study's limitations: (1) the focus solely on urban, agricultural, and natural systems; (2) the difficulty in getting municipal and other non-peer reviewed papers; and the small sample size. (3) The neglect of pertinent geographic, climatic, and other aspects. Over 80% of the world's water is consumed by urban and agricultural systems, although some nations or localities also have major industrial and recreational water use. This review would be complemented by future analyses of additional water usage, which would be beneficial for enhancing water management

techniques in all industries. White papers, municipal reports, and other publications that are not frequently found in academic databases may make up a significant portion of the pertinent literature, particularly for urban water management. Numerous documents outlining SWM assessments, procedures, difficulties, and solutions were probably missed in this review. A more thorough search for these reports might be advantageous for upcoming evaluations. Finally, a summary of the impact of country geography, climate, and other factors on SWM practises was outside the purview of this paper. Future studies may concentrate on a variety of factors to show how SWM practises can vary between close-by nations or be similar between far-off nations; pertinent exogenous factors may include climate, geology, and a more in-depth examination of historical and contemporary inter-country conflict, while relevant endogenous factors may include in-country wealth and resource distribution, socio-cultural traditions, and political stability.

5. CONCLUSIONS

SWM of environmental, agricultural, and urban systems is essential to continuous growth. There are numerous indicators and frameworks available for assessing sustainable management strategies. The interconnection of social and physical systems should be the main emphasis of these methods' advancements. Delivering water equitably is a concern in emerging regions, especially given the rapid urban population expansion. Plans for sustainable management should prioritise infrastructure development and stakeholder engagement in emerging regions, as well as water reclamation and reuse in developed regions. Although costs and dangers associated with technological adoption continue to be obstacles in both developing and developed countries, water reuse will lessen stress during drought years. By lessening competition between the agricultural sector and urban and environmental users, increases in crop water productivity can benefit each of the water user sectors covered in this article. While rainfed agricultural areas will gain from supplemental irrigation, crop water output in irrigated areas can be increased by altering crop water allocation and implementing efficient irrigation and on-farm technologies. If merely considering the immediate future, it can be observed that maintaining a sustainable water supply in natural systems is in conflict with development activities. The focus on water resource protection and restoration in industrialised countries is evidence that long-term economic prosperity is inextricably related to the health of the natural system. When making decisions to advance social and economic goals, thresholds for environmental degradation may be established using estimates of the value of ecosystem services. All regions can manage water resources in a way that promotes sustainable social, economic, and environmental development, while SWM will vary depending on geography and economic capacity.

References

1. Rio+20 from a Water Perspective. Available online: http://www.unwater.org/news-events/ news-details/en/c/207616/ (accessed on 1 February 2014).
2. United Nations World Commission on Environment and Development (UN WCED). *Our Common Future: Report of the World Commission on Environment and Development*; Document A/42/427; United Nations: New York, NY, USA, 1987.
3. Mays, L. *Water Resources Sustainability*; McGraw-Hill Professional: New York, NY, USA, 2006.
4. Loucks, D.; Gladwell, J. *Sustainability Criteria for Water Resource Systems*; Cambridge University Press: Cambridge, UK, 1999.
5. Alley, W.; Reilly, T.; Franke, O. *Sustainability of Ground–Water Resources*; US Department of the Interior, US Geological Survey: Denver, CO, USA, 1999.
6. United Nations. Agenda 21. In Proceedings of the United Nations Conference on Environment & Development, Rio de Janero, Brazil, 3–14 June 1992.
7. Mihelcic, J.R.; Crittenden, J.C.; Small, M.J.; Shonnard, D.R.; Hokanson, D.R.; Zhang, Q.; Chen, H.; Sorby, S.A.; James, V.U.; Sutherland, J.W.; *et al*. Sustainability science and engineering: The emergence of a new metadiscipline. *Environ. Sci. Technol.* **2003**, *37*, 5314–5324.
8. Larsen, T.; Gujer, W. The concept of sustainable urban water management. *Water Sci. Technol.* **1997**, *35*, 3–10.
9. Gleick, P. Basic water requirements for human activities: Meeting basic needs. *Water Int.* **1996**, *21*, 83–92.
10. *Ecosystems and Human Well-Being: Wetlands and Water Synthesis*; Millennium Ecosystem Assessment: Washington, DC, USA, 2005.
11. Melloul, A.J.; Collin, M.L. Harmonizing water management and social needs: A necessary condition for sustainable development. The case of Israel's coastal aquifer. *J. Environ. Manag.* **2003**, *67*, 385–394.
12. FAO AQUASTAT: Water withdrawal by sector, around 2006. Available online: www.fao.org/nr/water/aquastat/globalmaps/AquastatWorldDataEng_20121214_Withdrawal.pdf (accessed on 1 February 2014).
13. McDonald, R.I.; Green, P.; Balk, D.; Fekete, B.M.; Revenga, C.; Todd, M.; Montgomery, M. Urban growth, climate change, and freshwater availability. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 6312–6317.
14. Vairavamoorthy, K.; Akinpelu, E. Design of sustainable water distribution systems in developing countries. *ASCE World Water Congr.* **2001**, *44*, 1–10.
15. Rahmato, D. *Water Resource Development in Ethiopia: Issues of Sustainability and Participation*; Forum for Social Studies: Addis Ababa, Ethiopia, 1999.
16. Al-Qurashi, A.; Husain, T. Sustainable Water Resources Development Plan for the Middle-East Countries. In

Proceedings of the ASCE World Water Congress, Orlando, FL, USA, 20–24 May 2001.
17. Jiang, Y. China's water scarcity. *J. Environ. Manag.* **2009**, *90*, 3185–3196.
18. Gleick, P. Water, drought, climate change, and conflict in Syria. *Weather Clim. Soc.* **2014**, *6*, 331–340.
19. Conde, G. An indicator of conflict? Water in between Turkey, Syria and Iraq. *Reg. Cohes.* **2014**, *4*, 81–100.
20. Inocencio, A.; Kikuchi, M.; Tonosaki, M.; Maruyama, A.; Merrey, D.; Sally, H.; de Jong, I. *Costs and Performance of Irrigation Projects: A Comparison of Sub-Saharan Africa and Other Developing Regions*; International Water Management Institute: Colombo, Sri Lanka, 2007.
21. Russo, T.; Devineni, N.; Lall, U. Assessment of Agricultural Water Management in Punjab, India Using Bayesian Methods. In *Sustainability of Integrated Water Resources Management: Water Governance, Climate and Ecohydrology*; Setegn, S., Donoso, M., Eds.; Springer: Berlin, Germany, 2014.
22. Araus, J. The problems of sustainable water use in the Mediterranean and research requirements for agriculture. *Ann. Appl. Biol.* **2004**, *144*, 259–272.
23. Khan, S.; Tariq, R.; Yuanlai, C.; Blackwell, J. Can irrigation be sustainable? *Agric. Water Manag.* **2006**, *80*, 87–99.
24. Tiwari, P.C.; Joshi, B. Environmental changes and sustainable development of water resources in the Himalayan headwaters of India. *Water Resour. Manag.* **2011**, *26*, 883–907.
25. Benzerra, A.; Cherrared, M.; Chocat, B.; Cherqui, F.; Zekiouk, T. Decision support for sustainable urban drainage system management: A case study of Jijel, Algeria. *J. Environ. Manag.* **2012**, *101*, 46–53.
26. Daibes, F. Towards sustainable development in the water sector: A perspective from Palestine. *Water Sci. Technol.* **2000**, *42*, 81–86.
27. Antoniadis, A.; Takavakoglou, V.; Zalidis, G.; Darakas, E.; Poulios, I. Municipal wastewater treatment by sequential combination of photocatalytic oxidation with constructed wetlands. *Catal. Today* **2010**, *151*, 114–118.
28. Al-Jayyousi, O. Greywater reuse: Towards sustainable water management. *Desalination* **2003**, *156*, 181–192.
29. Voza, D.; Vukovic, M.; Carlson, L.; Djordjević, D.B. International water conflict and cooperation: The role of power relations among. *Int. J. Humanit. Soc. Sci.* **2012**, *2*, 56–66.
30. De Stefano, L.; Edwards, P.; de Silva, L.; Wolf, A.T. Tracking cooperation and conflict in international basins: Historic and recent trends. *Water Policy* **2010**, *12*, 871–884.
31. Starkl, M.; Brunner, N.; Lo, E.; Martı, L. A planning-oriented sustainability assessment framework for peri-urban water management in developing countries. *Water Res.* **2013**, *47*, 1–9.
32. Pearson, L.J.; Coggan, A.; Proctor, W.; Smith, T.F. A sustainable decision support framework for urban water management. *Water Resour. Manag.* **2009**, *24*, 363–376.
33. Postel, S. *Pillar of Sand: Can the Irrigation Miracle Last?*; W.W. Norton & Company: New York, NY, USA, 1999.
34. Pereira, L.S.; Cordery, I.; Iacovides, I. Improved indicators of water use performance and productivity for sustainable water conservation and saving. *Agric. Water Manag.* **2012**, *108*, 39–51.
35. Kumar, M.D.; Scott, C.A.; Singh, O.P. Can India raise agricultural productivity while reducing groundwater and energy use? *Int. J. Water Resour. Dev.* **2013**, *29*, 557–573.
36. Dinar, A.; Mody, J. Irrigation water management policies: Allocation and pricing principles and implementation experience. *Nat. Resour. Forum* **2004**, *28*, 112–122.
37. Johansson, R.C.; Tsur, Y.; Roe, T.L.; Doukkali, R.; Dinar, A. Pricing irrigation water: A review of theory and practice. *Water Policy* **2002**, *4*, 173–199.
38. Rockström, J.; Barron, J. Water productivity in rainfed systems: Overview of challenges and analysis of opportunities in water scarcity prone savannahs. *Irrig. Sci.* **2007**, *25*, 299–311.
39. Biazin, B.; Sterk, G.; Temesgen, M.; Abdulkedir, A.; Stroosnijder, L. Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa—A review. *Phys. Chem. Earth Parts A/B/C* **2012**, *47–48*, 139–151.
40. Fox, P.; Rockström, J. Water-harvesting for supplementary irrigation of cereal crops to overcome intra-seasonal dry-spells in the Sahel. *Phys. Chem. Earth* **2000**, *25*, 289–296.
41. Oweis, T.; Hachum, A. *Supplemental Irrigation: A Highly Efficiency Water Use Practice*; International Center for Agricultural Research in the Dry Areas (ICARDA): Aleppo, Syria, 2012.
42. Schuyt, K.D. Economic consequences of wetland degradation for local populations in Africa. *Ecol. Econ.* **2005**, *53*, 177–190.
43. Hirji, R.; Mackay, H.; Maro, P. *Defining and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa—A Summary*; SADC, IUCN, SARDC, World Bank: Washington, DC, USA, 2002.
44. Dixon, A.B.; Wood, A.P. Wetland cultivation and hydrological management in eastern Africa: Matching community and hydrological needs through sustainable wetland use. *Nat. Resour. Forum* **2003**, *27*, 117–129.
45. White, S.; Fane, S. Designing cost effective Water Demand Management Programs in Australia. *Water Sci. Technol.* **2002**, *46*, 225–232.
46. Dawadi, S.; Ahmad, S. Evaluating the impact of demand-side management on water resources under changing climatic conditions and increasing population. *J. Environ. Manag.* **2013**, *114*, 261–275.
47. Marlow, D.R.; Moglia, M.; Cook, S.; Beale, D.J. Towards sustainable urban water management: A critical reassessment. *Water Res.* **2013**, *47*, 7150–7161.
48. Le Maitre, D.; Colvin, C.; Maherry, A. Water resources in the Klein Karoo: The challenge of sustainable development in a water-scarce area. *S. Afr. J. Sci.* **2009**, *105*, 39–48.

49. Schaible, G.D.; Aillery, M.P. *Water Conservation in Irrigated Agriculture: Trends and Challenges in the Face of Emerging Demands*; US Department of Agriculture, Economic Research Service: Washington, DC, USA, 2012.
50. Ward, F.A.; Michelsen, A.M.; DeMouche, L. Barriers to water conservation in the Rio Grande Basin1. *J. Am. Water Resour. Assoc.* **2007**, *43*, 237–253.
51. Costanza, R.; D'Arge, R.; de Groot, R.; Farber, S. The value of the world's ecosystem services and natural capital. *Nature* **1997**, *387*, 253–260.
52. Buckle, J.S. Water demand management—Philosophy or implementation? *Water Sci. Technol.* **2000**, *4*, 25–32.
53. Marks, J.; Zadoroznyj, M. Managing sustainable urban water reuse: structural context and cultures of trust. *Soc. Nat. Resour.* **2005**, *18*, 557–572.
54. Grant, S.B.; Saphores, J.-D.; Feldman, D.L.; Hamilton, A.J.; Fletcher, T.D.; Cook, P.L.M.; Stewardson, M.; Sanders, B.F.; Levin, L.A.; Ambrose, R.F.; *et al*. Taking the "waste" out of "wastewater" for human water security and ecosystem sustainability. *Science* **2012**, *337*, 681–686.
55. Dixon, A.; Butler, D.; Fewkes, A. Water saving potential of domestic water reuse systems using greywater and rainwater combination. *Water Sci. Technol.* **1999**, *39*, 25–32.
56. Ellis, J.B. Sustainable surface water management and green infrastructure in UK urban catchment planning. *J. Environ. Plan. Manag.* **2013**, *56*, 24–41.
57. Pizzol, M.; Scotti, M.; Thomsen, M. Network Analysis as a tool for assessing environmental sustainability: Applying the ecosystem perspective to a Danish water management system. *J. Environ. Manag.* **2013**, *118*, 21–31.
58. Georgiou, P.E.; Papamichail, D.M. Optimization model of an irrigation reservoir for water allocation and crop planning under various weather conditions. *Irrig. Sci.* **2008**, *26*, 487–504.
59. Playán, E.; Mateos, L. Modernization and optimization of irrigation systems to increase water productivity. *Agric. Water Manag.* **2006**, *80*, 100–116.
60. Rajagopal-Durbin, A.; Durbin, T.J. Wells are not always water follies: Sustainable groundwater policies for the American west. *Water Policy* **2008**, *10*, 145–164.
61. Chapin, F.S.; Carpenter, S.R.; Kofinas, G.P.; Folke, C.; Abel, N.; Clark, W.C.; Olsson, P.; Smith, D.M.S.; Walker, B.; Young, O.R.; *et al*. Ecosystem stewardship: Sustainability strategies for a rapidly changing planet. *Trends Ecol. Evol.* **2010**, *25*, 241–249.
62. Horrigan, L.; Lawrence, R.; Walker, P. How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environ. Health Perspect.* **2002**, *110*, 445–456.
63. Gleick, P.; Chaleki, E.; Wong, A. Measuring Water Well-Being: Water Indicators and Indices. In *The World's Water 2002–2003: The Biennial Report on Freshwater Resources*; Island Press: Washington, DC, USA, 2002.
64. Ness, B.; Urbel-Piirsalu, E.; Anderberg, S.; Olsson, L. Categorising tools for sustainability assessment. *Ecol. Econ.* **2007**, *60*, 498–508.
65. Singh, R.K.; Murty, H.R.; Gupta, S.K.; Dikshit, A.K. An overview of sustainability assessment methodologies. *Ecol. Indic.* **2009**, *9*, 189–212.
66. Mori, K.; Christodoulou, A. Review of sustainability indices and indicators: Towards a new city sustainability index (CSI). *Environ. Impact Assess. Rev.* **2012**, *32*, 94–106.
67. Hellström, D.; Jeppsson, U.; Kärrman, E. A framework for systems analysis of sustainable urban water management. *Environ. Impact Assess.* **2000**, *20*, 311–321.
68. Juwana, I.; Muttil, N.; Perera, B.J.C. Indicator-based water sustainability assessment—A review. *Sci. Total Environ.* **2012**, *438*, 357–371.
69. Lawrence, P.R.; Meigh, J.; Sullivan, C. *The Water Poverty Index: An International Comparison*; Keele University: Staffordshire, UK, 2002.
70. *The Canadian Water Resources Sustainability Index (CWSI)*; Policy Research Initiative: Ottawa, ON, Canada, 2007.
71. Hsu, A.; Emerson, J.; Levy, M.; de Sherbinin, A.; Johnson, L.; Malik, O.; Jaiteh, M. *Environmental Performance Index*; Yale Center for Environmental Law and Policy: New Haven, CT, USA, 2014.
72. Chaves, H.M.L.; Alipaz, S. An integrated indicator based on basin hydrology, environment, life, and policy: The watershed sustainability index. *Water Resour. Manag.* **2006**, *21*, 883–895.
73. Ewing, B.; Reed, A.; Galli, A.; Kitzes, J.; Wackernagel, M. *Calculation Methodology for the National Footprint Accounts, 2010 Edition*; Global Footprint Network: Oakland, CA, USA, 2010.
74. Hoekstra, A.; Chapagain, A.; Aldaya, M.; Mekonnen, M. *The Water Footprint Assessment Manual: Setting the Global Standard*; Earthscan: London, UK, 2011.
75. Ulanowicz, R.E.; Goerner, S.J.; Lietaer, B.; Gomez, R. Quantifying sustainability: Resilience, efficiency and the return of information theory. *Ecol. Complex.* **2009**, *6*, 27–36.
76. Bagheri, A.; Hjorth, P. A framework for process indicators to monitor for sustainable development: Practice to an urban water system. *Environ. Dev. Sustain.* **2006**, *9*, 143–161.
77. Chung, E.-S.; Lee, K.S. Prioritization of water management for sustainability using hydrologic simulation model and multicriteria decision making techniques. *J. Environ. Manag.* **2009**, *90*, 1502–1511.
78. Lee, C. The determination of safe yield of underground reservoirs of the closed basin type. *Trans. Am. Soc. Civ. Eng.* **1915**, *78*, 148–251.
79. Todd, D. *Ground Water Hydrology*; John Wiley: New York, NY, USA, 1959.
80. Alley, W.; Leake, S. The journey from safe yield to sustainability. *Ground Water* **2004**, *42*, 12–16.

81. Bredehoeft, J. Safe yield and the water budget myth. *Ground Water* **1997**, *35*, 929.
82. Sophocleous, M. Managing water resources systems: Why "safe yield" is not sustainable. *Ground Water* **1997**, *35*, 561.
83. Bredehoeft, J.; Durbin, T. Ground water development—The time to full capture problem. *Ground Water* **2009**, *47*, 506–14.
84. Zhou, Y. A critical review of groundwater budget myth, safe yield and sustainability. *J. Hydrol.* **2009**, *370*, 207–213.
85. Mwanza, D.D. Water for sustainable development in Africa. In *The World Summit on Sustainable Development*; Springer: Berlin, Germany, 2005.
86. Peter, G.; Nkambule, S.E. Factors affecting sustainability of rural water schemes in Swaziland. *Phys. Chem. Earth Parts A/B/C* **2012**, *50–52*, 196–204.
87. Brown, R.R.; Farrelly, M.A. Delivering sustainable urban water management: A review of the hurdles we face. *Water Sci. Technol.* **2009**, *59*, 839–846.
88. Töpfer, K. Balancing competing water uses—A necessity for sustainable development. *Water Sci. Technol.* **2003**, *47*, 11–16.
89. Mbilinyi, B.P.; Tumbo, S.D.; Mahoo, H.F.; Senkondo, E.M.; Hatibu, N. Indigenous knowledge as decision support tool in rainwater harvesting. *Phys. Chem. Earth Parts A/B/C* **2005**, *30*, 792–798.
90. *The World's Women 2010: Trends and Statistics*; United Nations Department of Economic and Social Affairs (UN DESA): New York, NY, USA, 2010.
91. Niemczynowicz, J. Urban hydrology and water management—Present and future challenges. *Urban Water* **1999**, *1*, 1–14.
92. Rahman, M.A.; Ahsan, S.; Kaneco, S.; Katsumata, H.; Suzuki, T.; Ohta, K. Wastewater treatment with multilayer media of waste and natural indigenous materials. *J. Environ. Manag.* **2005**, *74*, 107–110.
93. Angin, I. An investigation on natural wastewater treatment system and re-usability of wastewater in irrigation. *J. Sustain. Agric.* **2007**, *31*, 83–90.
94. Kivaisi, A.K. The potential for constructed wetlands for wastewater treatment and reuse in developing countries: A review. *Ecol. Eng.* **2001**, *16*, 545–560.
95. Rockstrom, J.; Barron, J.; Fox, P. Water Productivity in Rain Fed Agriculture: Challenges and Opportunities for Smallholder Farmers in Drought-Prone Tropical Agro-Ecosystems. In *Water Productivity in Agriculture: Limits and Opportunities for Improvement*; CABI: Wallingford, UK, 2003.
96. Falcon, W.; Naylor, R. Rethinking food security for the twenty-first century. *Am. J. Agric. Econ.* **2005**, *87*, 1113–1127.
97. Khan, S.; Hanjra, M.A. Footprints of water and energy inputs in food production—Global perspectives. *Food Policy* **2009**, *34*, 130–140.
98. Tabor, J.A. Improving crop yields in the Sahel by means of water-harvesting. *J. Arid Environ.* **1995**, *30*, 83–106.
99. Ngigi, S.N.; Savenije, H.H.G.; Gichuki, F.N. Land use changes and hydrological impacts related to up-scaling of rainwater harvesting and management in upper Ewaso Ng'iro river basin, Kenya. *Land Use Policy* **2007**, *24*, 129–140.
100. Lundin, M.; Molander, S.; Morrison, G. A set of indicators for the assessment of temporal variations in the sustainability of sanitary systems. *Water Sci. Technol.* **1999**, *39*, 235–242.
101. *World Water Development Report (WWDR3) Water in a Changing World*; The United Nations Educational, Scientific and Cultural Organization (UNESCO): Paris, France, 2009.
102. Wichelns, D.; Oster, J.D. Sustainable irrigation is necessary and achievable, but direct costs and environmental impacts can be substantial. *Agric. Water Manag.* **2006**, *86*, 114–127.
103. Khan, S.; Hanjra, M. Sustainable land and water management policies and practices: A pathway to environmental sustainability in large irrigation systems. *L. Degrad. Dev.* **2008**, *487*, 469–487.
104. Tilman, D.; Cassman, K.G.; Matson, P.A.; Naylor, R.; Polasky, S. Agricultural sustainability and intensive production practices. *Nature* **2002**, *418*, 671–677.
105. Pimentel, D.; Pimentel, M. *Food, Energy and Society*; Colorado University Press: Niwot, CO, USA, 1996.
106. Smakhtin, V.; Revenga, C.; Döll, P. A pilot global assessment of environmental water requirements and scarcity. *Water Int.* **2004**, *29*, 307–317.
107. Richter, B.D.; Mathews, R.; Harrison, D.; Wigington, R. Ecologically sustainable water management: Managing river flows for ecological integrity. *Ecol. Appl.* **2003**, *13*, 206–224.
108. Poff, N.L.; Richter, B.D.; Arthington, A.H.; Bunn, S.E.; Naiman, R.J.; Kendy, E.; Acreman, M.; Apse, C.; Bledsoe, B.P.; Freeman, M.C.; *et al*. The ecological limits of hydrologic alteration (ELOHA): A new framework for developing regional environmental flow standards. *Freshw. Biol.* **2010**, *55*, 147–170.
109. Acreman, M.C.; Dunbar, M.J. Defining environmental river flow requirements—A review. *Hydrol. Earth Syst. Sci.* **2004**, *8*, 861–876.
110. Arthington, A.H.; Bunn, S.E.; Poff, N.L.; Naiman, R.J. The challenge of providing environmental flow rules to sustain river ecosystems. *Ecol. Appl.* **2006**, *16*, 1311–1318.
111. Marshall, R.M.; Robles, M.D.; Majka, D.R.; Haney, J.A. Sustainable water management in the southwestern United States: Reality or rhetoric? *PLoS One* **2010**, *5*, doi:10.1371/journal.pone.0011687.

112. Chou, C.; Neelin, J.D.; Chen, C.-A.; Tu, J.-Y. Evaluating the "rich-get-richer" mechanism in tropical precipitation change under global warming. *J. Clim.* **2009**, *22*, 1982–2005.
113. Held, I.; Soden, B. Robust responses of the hydrological cycle to global warming. *J. Clim.* **2006**, *19*, 5686–5699.
114. Malley, Z.J.U.; Taeb, M.; Matsumoto, T.; Takeya, H. Environmental sustainability and water availability: Analyses of the scarcity and improvement opportunities in the Usangu plain, Tanzania. *Phys. Chem. Earth* **2009**, *34*, 3–13.
115. Causapé, J.; Quílez, D.; Aragüés, R. Irrigation efficiency and quality of irrigation return flows in the Ebro River Basin: An overview. *Environ. Monit. Assess.* **2006**, *117*, 451–461.
116. Falkenmark, M.; Rockström, J. The new blue and green water paradigm: Breaking new ground for water resources planning and management. *J. Water Resour. Plan. Manag.* **2006**, *132*, 129–132.
117. Scanlon, B.R.; Jolly, I.; Sophocleous, M.; Zhang, L. Global impacts of conversions from natural to agricultural ecosystems on water resources: Quantity *versus* quality. *Water Resour. Res.* **2007**, *43*, doi:10.1029/2006WR005486.
118. Yang, H.; Wang, L.; Abbaspour, K.C.; Zehnder, A.J.B. Virtual water trade: An assessment of water use efficiency in the international food trade. *Hydrol. Earth Syst. Sci.* **2006**, *10*, 443–454.
119. Rosegrant, M.; Cai, X. Global water demand and supply projections global water demand and supply projections Part 2. Results and prospects to 2025. *Water Int.* **2002**, *27*, 170–182.
120. Steward, D.R.; Bruss, P.J.; Yang, X.; Staggenborg, S.A.; Welch, S.M.; Apley, M.D. Tapping unsustainable groundwater stores for agricultural production in the high plains aquifer of Kansas, projections to 2110. *Proc. Natl. Acad. Sci. USA* **2013**, *110*, E3477–E3486.
121. Irmak, S. *Plant Growth and Yield as Affected by Wet Soil Conditions due to Flooding or Over-Irrigation*; University of Nebraska-Lincoln Extension: Lincoln, NE, USA, 2014.
122. Van Iersel, M.; Seymour, R.M.; Chappell, M.; Watson, F.; Dove, S. Soil moisture sensor-based irrigation reduces water use and nutrient leaching in a commercial nursery. *Proc. South. Nurs. Assoc. Res. Conf*. **2009**, *54*, 17–21.
123. Stroosnijder, L.; Moore, D.; Alharbi, A.; Argaman, E.; Biazin, B.; van den Elsen, E. Improving water use efficiency in drylands. *Curr. Opin. Environ. Sustain.* **2012**, *4*, 497–506.
124. Scott, C.A. The water-energy-climate nexus: Resources and policy outlook for aquifers in Mexico. *Water Resour. Res.* **2011**, *47*, doi:10.1029/2011WR010805.
125. Ward, F.; Pulido-Velazquez, M. Water conservation in irrigation can increase water use. *Proc. Natl. Acad. Sci. USA* **2008**, *105*, 18215–18220.