A Literature Review of Impacts of Urbanization on Water Resource Management: A Case Study in South Africa

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Abstract- As urban space continues to expand to accommodate a growing global population, there remains a real need to quantify and qualify the impacts of urban space on natural processes. The expansion of global urban areas has resulted in marked alterations to natural processes, environmental quality and natural resource consumption. The urban landscape influences infiltration and evapotranspiration, complicating our capacity to quantify their dynamics across a heterogeneous landscape at contrasting scales. Impervious surfaces exacerbate runoff processes, whereas runoff from pervious areas remains uncertain owing to variable infiltration dynamics. Increasingly, the link between the natural hydrological cycle and engineered water cycle has been made, realizing the contributions from leaky infrastructure to recharge and runoff rates. Urban landscapes are host to a suite of contaminants that impact on water quality, where novel contaminants continue to pose new challenges to monitoring and treatment regimes. This paper focuses on the impacts of urbanization on water resource management using South Africa as a Case study.

Index Terms- Urbanization, Water Resources, Runoff, Impervious Surfaces, Hydrology

I. INTRODUCTION

Water stress has become a major concern in most urban areas. According to Rosegrant, Cai and Cline (as cited from Jansen, 2012), water development is essential to the livelihood of people, as well for ensuring growth in the industrial sector and for environmental sustainability. Water is essential for human life. Water availability is influenced by factors such as climate change, urbanization and pollution, which affect both the quantity and quality of surface water and groundwater (Jansen, 2012).

Rapid urban population growth coupled with inadequate planning and resource management can pose significant social and economic consequences. Rapid urbanization is a global phenomenon, approximately 54% of the world population live in urban areas and this number is expected to increase by the year 2050 (Maria E. Freire; Somik Lall & Danny Leipziger, 2014). The world population is growing relatively fast and as a result water consumption is likely to double. Urbanizations is among the main factors that affect water supply and consumption in urban areas. According to Wua & Tanb (2012) urbanization has been and is the major cause for current water shortage and water environment changes; and the deteriorating urban water supply/demand balance arising from massive urban population increase.

The World Bank (2017) stated that by the year 2025 approximately 1.8 billion people will reside in regions/counties with absolute water scarcity. Water is a very scarce resource and it needs to be utilized efficiently on an equitable basis in order to

meet all the competing demands. Failure to recognize the economic value of water can lead to wasteful and environmentally damaging uses of this resource. Urbanization directly affects the availability and management of water resources. Total urban water demand will increase continuously along with urbanization and if appropriate action is not taken to better plan and mitigate the negative impacts of urbanization on water resources, humanity will be adversely affected.

This paper focuses on the impacts of urbanization on water resource management using South Africa as a Case study. Countries such as South Africa, China and India are all among those that are presently experiencing water shortages and all striving to achieve sustainable urbanization simultaneously with improved and integrated water resource management.

II. THE CURRENT STATUS

As economies of countries continue to boom they are most likely to be accompanied by expanding cities and growing urban industries and in turn would most likely, without exception, have to face major water shortage and other resultant environment problems. It is estimated that with the current practices the world will experience a 40% shortfall between the demand and available supply of water by 2030 (World Bank, 2017). These figures are further aggravated by the current chronic water scarcity, hydrological uncertainty, extreme weather conditions of floods and droughts, rapid development, pollution and inefficient utilization of water. Water scarcity and security is largely becoming a major challenge for many countries. Water resources are dwindling and this has profound implications for food security, people's health and the functioning of aquatic ecosystems.

The importance of safeguarding the quality of water in urban areas has also largely gained prominence and urban water resources are now regarded as important environmental asset. Thus the design of the urban form is now subjected to greater scrutiny and innovations which are to be adopted in order to minimize its ecological footprint in relation to the water environment (Goonetilleke & Thomas, 2004).

The relationships between urban form and water quality are not intuitively obvious however, as McGrane (2014) observe, urban spaces simultaneously expand with population increase.

This expansion of urban space leads to alterations to natural processes, environmental quality and natural resource consumption. The built up environment has an effect on the infiltration and evapotranspiration as it involves erection of impervious surfaces which exacerbate runoff processes, whereas runoff from pervious areas remains uncertain owing to variable infiltration dynamics.

This paper also tries to provide a broader understanding of the relationship between urbanization and water resource management, looking at the issues that exist and exploring mitigation measures to ensure sustainable and equitable use.

III. AIM OF THE REVIEW

In the past 20 years, available fresh water resources in Africa have greatly reduced due to severe and prolonged droughts(Donkor & Wolde, 2000). Water pollution resulting from industrial effluent, urban runoff, sewerage and agro-chemicals are on the increase and continue to deteriorate freshwater quality and affect its quantity. The aim of this research is to establish the various impacts of urbanization on water resource management focusing on urban water quality and shortage.

IV. OBJECTIVES

The objectives of this paper are as follows:

- To appraise the Government, City Planners, Administrators and all relevant stakeholders about the effects of urbanization water resources and equip them with the necessary information and understanding to enable them to better plan for the future.
- Raise awareness of the importance of protecting water resources, water quality and aquatic ecosystems.
- To provide an in depth understanding of the relationship between the water cycle and urbanization
- Explore challenges faced in developing countries (South Africa) when it comes to water resource management.

V. TRENDS IN URBANIZATION AND ITS IMPACTS ON WATER RESOURCES MANAGEMENT

Water Resource Management and Urbanization in South Africa

South Africa is a developing country with a total population of about 57 million, according to the United Nations (as cited from Jansen, 2012). South Africa's projected urban population for 2010 was 61.7% of the total population, as compared to 79.6% projected for 2050. With these figures South Africa can be regarded as one of the most urbanized countries in Africa. According to Edmonds (2013) presently nearly two-thirds of South Africa's population of 50 million lives in urban areas. South Africa's rapid urbanization occurred predominantly during the postcolonial 20th century.

South Africa is a water-stressed country with an average annual rainfall of 500mm (60% of the world average). Only a narrow region along the south-eastern coastline receives good rainfall, while the greater part of the interior and western part of the country is arid or semi-arid. 65% of the country receives less than 500m per year, which is usually regarded as the minimum for dryland farming; 21% of the country receives less than 200mm per year (DWAF 1994). Four of South Africa's main rivers are shared with other countries, which together drain about 60% of the country's land area and contribute about 40% of its total surface runoff (river flow).

The natural availability of water across the country is variable, and rainfall displays strong seasonality. Stream flow in South African rivers is at a relatively low level for most of the year. This feature limits the proportion of stream flow that can be relied upon for use. Moreover, as a result of the excessive extraction of water by extensive forests and sugar cane plantations in the relatively wetter areas of the country, only 9% of the rainfall reaches the rivers, compared to a world average of 31% (DWAF 1996).

Water availability across South Africa is faced with the following major challenges (Anon., n.d.): Uneven spatial distribution and seasonality of rainfall (43% of the rain falls on 13% of the land). Relatively low stream flow in rivers most of the time, which limits the proportion of stream flow that can be relied upon for use, Location of major urban and industrial developments remote from the country's larger watercourses, which necessitates large-scale transfers of water across catchments. Urbanization is largely influencing water demand in South Africa and will increase future water requirements and lastly Climate change causing significant changes to precipitation patterns. These challenges represent the urgent need to adequately manage and conserve water resources. According Phyllis & Pramod (2011) the current trends in South Africa indicate that, water problems will continue becoming more complex, conflicting and interfering with other developmental sectors such as: agriculture, mining and energy, industry, transportation and communications and with social sectors including education, environment, health, rural and regional development. Water issues touch all segments of society and all economic sectors. According to the State of the

Environment (as cited from Jansen, 2012), increasing temperatures and higher variability in precipitation will lead to floods in certain areas, and drought in others.

Water resource management plays a critical role in ensuring food and ecological security. Despite the importance water assumes in overall human development, it is among the most mismanaged resources in South Africa (Phyllis & Pramod, 2011).

The figure (1) below

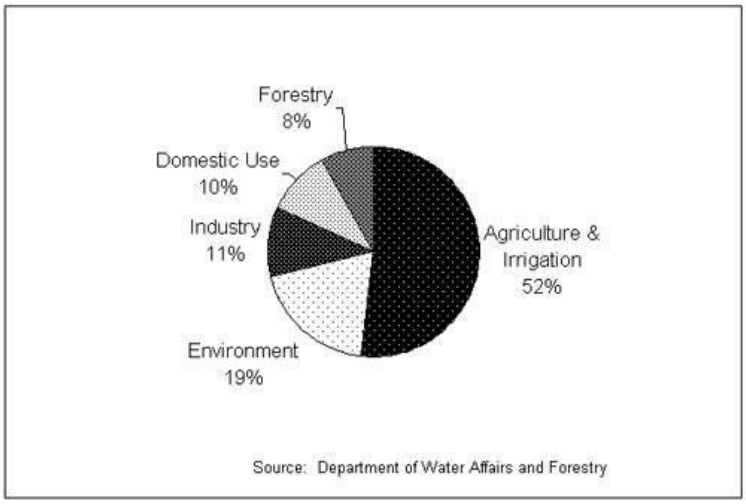

Fig 1: shows water allocation and usage in South Africa. *Jacobson (as cited from Phyllis & Pramod, 2011)*

Figure 1 indicates that agriculture and irrigation is allocated 52% of the water while only 10% is allocated for domestic use. The industry takes 11% and the remaining is left for forestry and the environment. Figure highlights the huge imbalances in water allocation. Further indicating the mismanagement of water resources and emphasizing the need for proper legislations on water management in South Africa. However, considering that South Africa is a developing country perhaps it makes much sense that agriculture and irrigations takes a big portion. In South Africa, there is a gross under-utilization or inefficient utilization of water resources hence there is a need to put land and water resources potentials to productive use. Development should proceed on basis of sound policies and proper planning strategies that take into account the interfaces and interlinkages with the national socio-economic development perspectives (Donkor & Wolde, n.d.).

Phyllis & Pramod (2011) stated that recent national water policy document lacks substances, direction and seriousness in addressing the real issues pertaining to water. The Global Water Partnership (2013) also stated that the Current models of urban planning and water management in South Africa have already failed or likely to fail from the perspective of cost effectiveness, technical performance, social equity, and environmental sustainability. This requires a shift in paradigm perhaps a shift towards an Integrated Urban Water Management (IUWM) which would serve to provide a framework for interventions over the entire water cycle and a reconsideration of the way water is used and reused (Global Water Partnership, 2013).

According to Global Water Partnership (2013) the principles of Integrated Urban Water Management (IUWM) include the following three main inter connected dimensions:

- **Governance**: critical aspect for supporting IUWM. Without government policy and framework support and comprehensive stakeholder participation, optimum management of water resources cannot be achieved.
- **Service**: This component includes closed loop systems for water supply and sanitation (making whole water cycle as one), storm water management, good Operation & Maintenance and at the same time maintaining the water quality as required for use. Decentralized wastewater treatment systems and innovative via utilizing affordable technologies.
- **Resource**: making use of available resources; conventional or unconventional in the form of wastewater, rainwater, surface water, grey water and black water etc. Wastewater is not wasted water! Simultaneously, demand side management should be utilized to lessen the stress on water resources.

VI. URBANIZATION AND THE WATER CYCLE

The water cycle is the continuous exchange of water between the land, waterways, and atmosphere (California NEMO Partnership, n.d.). Urbanization is characterized by an increase of impervious/hard surfaces, this includes rooftops and pavement and parking lots. This decreases the amount of water that infiltrates into the ground. The consequences of these land modifications include changes in water supply from altered hydrologic processes of infiltration, groundwater recharge, and runoff; water quality degradation from urban runoff and combined sewer overflows (CSOs); and changes in water demand (Chen, et al., 2017).

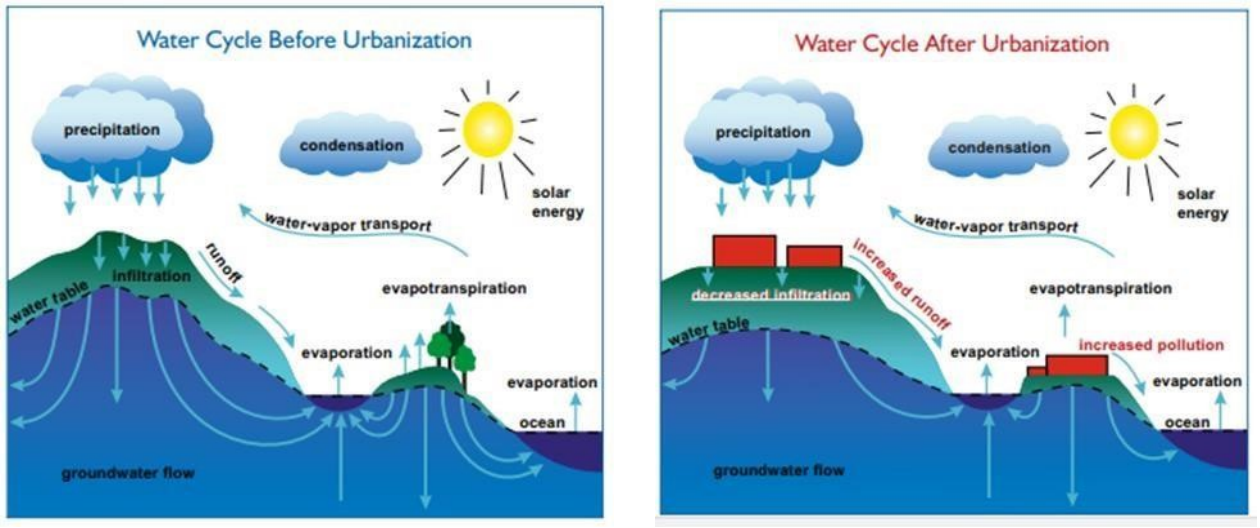

Fig 2: Shows the effects of urbanization (Donaldson, n.d.)

Surface runoff and river discharge will increase if vegetation decreases. When urbanization takes place, the vegetation decreases due to the construction of impervious surfaces. Impervious surfaces contribute to surface runoff due to decreased infiltration (Chen, et al., 2017). According to Bhaduri et al., 2001; Suriya and Mudgal, 2012 (as cited by Chen et al, 2017) reduced infiltration leads to higher peak flows, even for short duration low intensity rainfall, and increases the risk of flooding.

The following are the water cycle problems associated with urbanization as identified by the City of Melbourne (n. d.): Pollution, Waterway flushing, Flooding and Decreased soil moisture

In summary, increased impervious cover associated with urbanization alters the natural cycling of water. Changes in the shape and size of urban streams, followed by decreased water quality, are the most visible effects of increased imperviousness (California NEMO Partnership, n.d.). Alterations in the aquatic environment associated with these hydrological changes greatly compromise the normal functioning of waterways (California NEMO Partnership, n.d.).

Following urbanization, the consequences are most likely to be increased frequency and severity of flooding, channel erosion, and destruction of aquatic habitat.

VII. URBANISATION AND WATER RESOURCE MANAGEMENT

Urbanization represents a number of benefits and consequences. The benefits include provision of convenience of infrastructure, goods and services needed by people, government, economic development, industry, and trade and the consequences include; land surface modifications including vegetation reduction, soil compaction, and change from pervious surfaces to impervious surfaces such as roofs, roads, and parking lots (Chen, et al., 2017). Population growth, rapid urbanization and industrialization, the expansion of agriculture and tourism, and climate change all put water under increasing stress. Given this growing pressure it is critical that this vital resource is properly managed. Urban runoff also carries non-point source pollutants, such as oil, grease, metals, and pesticides, into streams and rivers during rainfall events.

On the positive side urbanization has led birth of gigantic cities, it has opened up new opportunities, and importantly it has led to competition at national and international levels. While on the negative side, it has led to a series of health hazards. It has been reported that urbanization is not only causing land use change but excessive use of energy and resources have overburdened the ecosystem and has worst implications on the human health (Kelly et al., 2008).

Rapid urbanization is in an alarming state in many developing countries because of the associated problems such as unemployment, economic crisis, health issues, poor sanitation, increase in urban slums, and degradation of ecosystem (Adepoju, 1993). Increased urbanization and demographic trends for employment, food security, water supply, and shelter and sanitation implications, especially the disposal of wastes (solid and liquid) that the cities produce are overwhelming (Goodland et al., 1992). Water shortage and pollution are among the developed world’s greatest challenges. Related to such challenges are the issues of water scarcity and water pollution in the developing world. The safe drinking water supply is important in terms of both quality and quantity as it is essential to human existence (Shilling and Manahan, 1994). As the civilization evolved, human activity increases and changes occur in the nature of pollutants entering into watercourses (Hussain et al., 2014). Rivers are waterways of strategic importance across the world, providing main water resources for domestic, industrial and agricultural purposes (Singh et al., 2009).

Change in land use from ‘‘agriculture’’ or ‘‘barren’’ to urban results in Reduction in evapotranspiration and change in groundwater recharge. A change from unpaved to paved results in Reduction in groundwater recharge (% of rainwater infiltrating) and runoff. Increase in number and location of commercial establishments Increases in commercial demand for water in each census area. Change in population density and spatial location, Change in quantity and location of urban water demand.

Figure 3, illustrates traditional drainage approach which also introduces significant alteration to water quality as pollutants deposited on hard surfaces are transported with runoff to the receiving waters. These pollutants come from varied catchment sources, ranging from natural atmospheric deposition to ill-controlled industrial activities (Urrutiaguer, 2016)

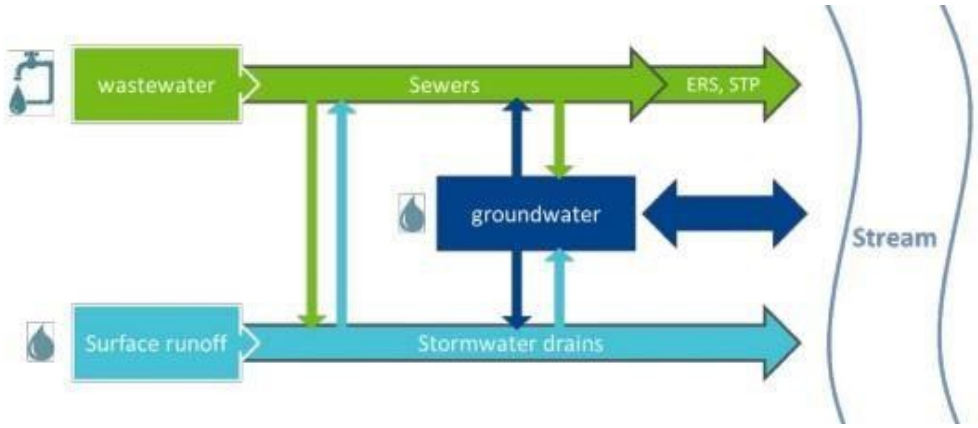

Figure3: traditional drainage approach (Urrutiaguer, 2016)

Moreover, as the urban population grows, so does the demand for water and sanitation facilities. If this is not accompanied by an expansion of the appropriate water infrastructure facilities, water quality will be affected. In addition, climatic conditions can also alter the demand for water: increased temperatures may cause people to consume more water. Other factors that influence the demand side are changes in the irrigation requirements of the agricultural sector and increased water consumption by manufacturers. (Jansen, 2012).

VIII. STRATEGIES FOR SUSTAINABLE WATER SUPPLIES

Demand Management

A key challenge for sustainable development in South Africa is reconciliation of water demand and supply both for the medium and long term. While there is planning for future sources of water supply, it appears as if demand has been neglected. Reducing demand can increase supply thereby creating a greater margin of safety for future droughts. This can be through a range of measures that 'encourage efficient water use including education, voluntary compliance, pricing policies, legal restrictions on water use, rationing of water or the imposition of water conservation standards on technologies' (Schulze & Perks 2000: 108). **Water Services Losses**

The domestic sector accounts for 15% of total national use and has the highest expected growth in demand. The level of unaccounted for water in urban distribution systems is between 15 and 20%, which is viewed as high by international standards (Goldblatt et al 2002). Efficient use of water will reduce treatment and distribution costs.

Control of Water Quality

Polluted water that is unfit for drinking or other uses can have a similar effect as reduced water supply. Reducing water pollution effectively increases the supply of water, which in turn increases the safety margin for maintaining water supplies during droughts (Schulze & Perks 2000). The protection of water quality presents a major challenge to water policy in South Africa.

Allocation of Water Supplies by Market-Based Systems.

Most policy papers dealing with natural resource management in South Africa recognize the need for economic instruments and market mechanisms for efficient utilization and allocation of natural resources and environmental resources. The provision of water at prices below the true economic value is considered the main reason for inefficient use of water and allocation in South Africa. Further, in the context of water scarcity, an argument can be made for the introduction of economic incentives in water-stressed catchments to encourage the conservation of water and its shift from low Water resource management and climate change in South Africa to higher value use. This can be done administratively or by using market-related mechanisms. Issues to be considered when reviewing the pricing of water are (Hassan et al 1996): Marginal cost pricing is more appropriate than average cost pricing since it sends the right signal to efficient water users. Variable tariff rates, as opposed to flat rates, to provide for periods of scarcity and peak demands. Opportunity cost of water, especially when water is scarce. Pricing undelivered water i.e. rainfall runoff that is absorbed by crops vs natural vegetation. Property rights and tradable permit systems in water. Lifeline tariffs and equity. Rewarding quality return flows from waste streams. Market-based allocations are able to respond more rapidly to changing conditions of supply and also tend to lower the water demand, conserve water and consequently increase both the robustness and resilience of the water supply system (Schulze & Perks 2000).

Modification of Catchment Vegetation

Through the modification of the vegetation in various catchments, where water-thirsty vegetation with high transpiration rates has reduced the stream flow, the available water supply can be increased. Invading alien plants have covered some 10 million hectares, about 8%, of South Africa. They cause the loss of some 7% of the annual flow in South Africa's rivers each year – about 33 million m3 of water. (This excludes their severe impact upon groundwater reserves.) Through the Working for Water Programme it is estimated that approximately 750 000 hectares will need to be cleared each year over a 20-year period (Kasrils 2000).

Planning for Drought

Much research has been conducted into the adaptation to climate variability (droughts and floods) and specifically measures that could be taken to prevent or minimize the disruption and damage caused by such occurrences.

In the past, most of this research has been conducted in agricultural sector; more recently research has been focused on the impacts of drought and floods on people and their livelihoods. The lessons from this research, and resilience strategies of vulnerable communities, need to be taken into consideration when developing strategies to deal with the impacts of future long-term climate change. If the development goals of the country are to be achieved despite the impacts of climate change, then the appropriate lessons need to be incorporated into national and local water management policy. The cost of developing contingency plans to adapt to water shortages and mitigate droughts is relatively small compared with the potential benefits (Schulze & Perks 2000).

Improved Monitoring and Forecasting Systems for Floods and Drought

It is possible that climate change will affect the frequency of floods and droughts. Monitoring systems will help in coping with these changes, even without the impact of climate change (Schulze & Perks 2000).

Inter-Basin Transfers

Transfers of water between basins may result in more efficient water use under the current and future changed climate. Inter-basin transfers are considered an effective short-term measure for addressing drought and water supply on a regional scale. This, however, is an expensive option (Schulze & Perks 2000).

Marginal Changes in Construction of Infrastructure

Marginal increases in the size of dams or marginal changes in the construction of canals, pipelines, pumping plants and storm drainage should be considered (Schulze & Perks 2000).

Maintain options for new sites

Potential sites for new dams should be kept open till they are required, since there are a limited number of sites that can be used efficiently as reservoirs and removing structures once an area has been developed may be very costly or politically difficult (Schulze & Perks 2000).

IX. FINDINGS/OBSERVATIONS

There is a direct relationship between urbanization and water resource management. Various published literature from various authors has confirmed this fact. However most of the impacts are related to water shortages for the urban population as well as ensuring water quality. This perhaps calls for a more integrated and sustainable approach, linking social and economic development with protection of natural ecosystems

The most visible impacts of urbanization are the changes in the shape and size of urban streams, followed by decreased water quality, which is the immediate consequence increased imperviousness. Waterways are severely degraded by urbanization. Further growth of our cities represents a major risk to waterway health as there is strong evidence showing that continuation of current urbanization practices, storm water management practices in particular, will result in severe degradation across countries.

X. CONCLUSION

The South African rapid urbanization has shown a potential effect on environment, water resources & its quality, soil salinity and urban infrastructures. The water resources are steadily degrading and could potentially form an environmental hazard. The impact of urbanization on the aquifer complexes is very varied. The greatest hydrogeological impacts of urbanization are found on the flat surfaces of the high terraces and the interfluves. The frequency of extreme hydrological events has been increased due to increase runoff causes more intense local flooding, while droughts during dry weather are deeper and longer. These changes have started showing their impact in South Africa on water habitats, exporting high concentration of pollution into the rivers, wetlands and reservoirs, destabilizing ecological processes, handicapping ecological stability of ecosystems. As a result, the findings of this study demonstrated that:

- There is growing imbalance between demand and supply of water. Both surface and groundwater quality is deteriorating due to urbanization.
- Urbanization has led to the lowering of water levels in many urban localities due to abstraction. This has shown a major impact on the surface environment.
- Poorly developed drainage systems/no drainage systems in cities causes frequent flooding leading to the spreading of viral and epidemic diseases.
- Groundwater run-off, infiltration rate and recharge have reduced and water storage is much lower.
- Frequency of surface runoff has increased.
- South Africa has high density of population. This dense population coupled with high growth rate, which is generating huge demand for additional water.

XI. RECOMMENDATIONS

Increasing urban population growth continues to set a heavy demand on water and other natural resources. This calls for an increased focus on the management of water as a finite resource which requires co-ordination and integration of water, land-use, and population policies for sustainable development. This also requires pulling efforts of relevant stakeholders to actively participate to tackle these issues and to better plan for the future. This includes users, planners and policy-makers at all levels.

The current challenges also call for a review and amendment of the current policies to bring them up to date with the status quo and to ensure integration from all levels of government with an integrated effort to ensure optimal utilization and distribution of water. This is also necessary to ensure adequate funds are allocated to ensure better management of water resources which is currently marginalized and to put measures in place to improving water use efficiency and to reducing wastage and damage to natural resources by rehabilitating infrastructures. There is very little compressive study that look into the quality of urban form and the role that urban planning can play in insuring water quality and mitigating the negative impacts of urbanization on the environmental resources. A good example is the use of high density residential development which results in a relatively smaller footprint.

Water not used in a consumptive manner should be re-used or recycled. This could be either by returning the water back to the river in a fit state for further use downstream or for reuse within the system from which it was first abstracted, specifically for industrial and domestic users. Coastal towns specifically could look to recycling as a potential source of additional water, before discharging waste water to the sea. Reduction of losses due to agriculture, as stated before, irrigation accounts for almost 60% of water used in South Africa. There are significant losses in many distribution and irrigation systems as well significant evaporation losses. Alternative irrigation methods and practices should be investigated.

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REFERENCES

[1] Adepoju, A. (1993). The impact of structural adjustment on the population of Africa: The implications for education, health and employment. London: UNPFA, Heinemann and James Currey.W.-K. Chen, *Linear Networks and Systems* (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.

[2] Anon., n.d. Overview of the South African Water Sector. In: *Governing Board Induction Manual.* s.l.: s.n., pp. 1-35.

[3] California NEMO Partnership, n.d. *How Urbanization Affects the Water Cycle,* South California: California NEMO Partnership.

[4] Chen, J. et al., 2017. Urbanization impacts on surface runoff of the contiguous United State.

[5] Journal of Environmental Management, Volume 187, pp. 470-481.

[6] Cohen, B., 2004. Urban growth in developing countries: a review of current trends and a caution regarding existing forecasts. World Development 32 (1), 23–51.

[7] City of Melbourne, n.d. *How does urbanization impact the water cycle?* [Online] Available at: http://urbanwater.melbourne.vic.gov.au/melbournes-water-story/howdoesurbanisation-impact-the-water-cycle/ [Accessed 8 12 2017].

[8] Donaldson, S., n.d. *Effects of Urbanization on the Water Cycle.* [Online] Available at: https://www.unce.unr.edu/publications/files/nr/2004/FS0443.pdf [Accessed 23 12 2017].

[9] Donkor, S., & Wolde, Y. E. (2000). Intergrated Water Resource Management in Africa: Issues and Options. *Integrated Wetlands and Water Resources Management*, 3.

[10] Available at : http://archive.ramsar.org/doc/wurc/wurchbk4cs1.doc Accessed 22/5/2019DWAF 1994. Water Supply and Sanitation Policy – White Paper. Water – an indivisible national asset. Cape Town

[11] DWAF 1996. The working for water Programme annual report 1995/96. Pretoria, DWAF

[12] Edmonds, I., 2013. *Urbanization in South Africa.* [Online]

[13] Available at: https://my.vanderbilt.edu/f13afdevfilm/2013/09/urbanization-in-south-africa/ [Accessed 20 12 2017].

[14] Goodland, R.J., Daly, H.E. and S. El Serafy (1992). Population, technology, and lifestyle: The transition to sustainability. Island Press

[15] Global Water Partnership, 2013. *Water and Urbanization.* [Online]

[16] Available at: http://www.gwp.org/en/CRITICAL-CHALLENGES1/Water-and-Urbanisation/ [Accessed 22 12 2017].

[17] Goonetilleke, A. & Thomas, E., 2004. *Water quality impacts of urbanization: Relating water quality to urban form.,* Queensland: Queensland University of Technology, Centre for Built Environment and Engineering Research.

[18] Goldblatt, M, Gelb, S & Davies, G 2002. Macroeconomics and sustainable development in Southern Africa. Development Bank of Southern Africa.

[19] Hassan, R, Breen, C & Mirrilees, R 1996. Management of Water Resources and Emerging Water Policy Challenges in South Africa. The Economics, Policy & Natural Resource Management Southern Africa Workshop, Pretoria, 1996. IUCN.

[20] Hussain, R., Ali, L., Hussain, I. and S.A. Khattak (2014). Source identification and assessment of physico-chemical parameters and heavy metals in drinking water of Islampur area, Swat, Pakistan. Journal of Himalayan Earth Sciences, 47(1): 99-106.

[21] Jansen, A. I., 2012. Aspects of the Economics of Water Management in Urban Settings in South Africa, with a focus on Cape Town, South Africa: Stellenbosch University.

[22] Kasrils, R 2000. A water perspective on invasive species. The best management practices symposium, Kirstenbosch

[23] Kelly, T., Yang, W., Chen, C.-S., Reynolds, K. and J. He (2008). Global burden of obesity in 2005 and projections to 2030. International Journal of Obesity, 32(9): 1431- 1437.

[24] Lundqvist, J., Appasamy, P., Nelliyat, P., 2003. Dimensions and Approaches for Third World City Water Security, Philosophical Transactions: Biological Sciences, 1440 ed. Freshwater and Welfare Fragility: Syndromes, Vulnerabilities and Challenges, p. 1985

[25] Maria E. Freire; Somik Lall & Danny Leipziger, 2014. *Africa's Urbanization: Challenges and Opportunities.* Washington, DC: Korea Development Institute (KDI).

[26] McDonald, R.I., Green, P., Balk, D., Fekete, B.M., Revengaa, C., Todd, M., Montgomery, M., 2011. Urban growth, climate change, and freshwater availability. Proceedings of the National Academy of Sciences 108 (15), 6312–6317.

[27] McGrane, S. J., 2014. Urbanization and its Impact on China's Water Resources. [Online] Available at:

[28] http://www.tandfonline.com/doi/pdf/10.1080/02626667.2015.1128084?needAccess=true [Accessed 05 12 2017].

[29] Phyllis, M. I. & Pramod, S., 2011. *Management of water resources in South Africa – a review*, Johannesburg: University of South Africa.

[30] Seto, K.C., Sa´nchez-Rodrı´guez, R., Fragkias, M., 2010. The new geography of contemporary urbanization and the environment. Annual Review of Energy and Environment 35 (1), 167–194.

[31] Seto, K.C., Satterthwaite, D., 2010. Interactions between urbanization and global environmental change. Current Opinion in Environmental Sustainability 2 (3), 127–128

[32] Singh, K.P., Basant, A., Malik, A. and G. Jain (2009). Artificial neural network modeling of the river water quality—A case study. Ecological Modelling, 220(6): 888-895.

[33] Schulze, R & Perks, L 2000. Assessment of the Impact of Climate Change on Hydrology and Water Resources in South Africa. ACRU cons report 33. Pietermaritzburg, School of Bio Resources Engineering and Environmental Hydrology, University of Natal. January 2000.

[34] Shilling, F.M. and D.T. Manahan (1994). Energy metabolism and amino acid transport during early development of Antarctic and temperate echinoderms. The Biological Bulletin, 187(3): 398-407

[35] The World Bank, 2017. *WATER RESOURCES MANAGEMENT*. [Online] Available at: http://www.worldbank.org/en/topic/waterresourcesmanagement [Accessed 04 12 2018].

[36] Urrutiaguer, M., 2016. Management of the ecological impacts of urban land and activities on waterways, Melbourne: Melbourne Water Corporation.

[37] United Nations, 2001. World Urbanization Prospects of Population Growth: The 2001 Revision. Population Division, United Nations, 2 United Nations Plaza, Room DC2-1950, New York, NY 10017, USA

[38] Wua, P. & Tanb, M., 2012. Challenges for sustainable urbanization: a case study of water shortage and water environment changes in Shandong, China. *Procedia Environmental Sciences*, Volume 13, p. 919 – 927.

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