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Review

Sustainable Living in Africa: Case of Water, Sanitation, Air Pollution and Energy

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Abstract: The study reviewed developmental challenges confronting African countries with specific reference to the availability of potable water, sanitation, energy, water and ambient air. It showed the conflict between the need to exploit environmental capital in order to keep up with the pace of human development activities and the need to utilize resources sustainably. Hitherto, the cost of this development has been at the expense of public health and cleaner environment. The outcome demonstrates the need for a change of approach in the way and manner that environmental resources are exploited for developmental purposes. Two concepts for addressing these problems were discussed. These are the "soft path" approach and the trialog model. The former places high priority on the proper use and management of existing infrastructure or resources rather than acquisition or exploitation of more infrastructure or resources. The latter concept addresses the principle of resource governance through the application of an understanding of the complex relationship between the main stakeholders—government, science, and society. Case studies on the practicality of these concepts were also highlighted and discussed.

Keywords: environment; water; energy; air; pollution; development

1. Introduction

Sustainable development has been classified into three broad areas–environmental, economic and socio-political. The concept of sustainable development itself discusses ways of meeting current human needs without depriving future generations of the right and access to the same resources [1–3]. In the attempt to satisfy current human needs, a great deal of environmental capital (naturally occurring resources) is used up, sometimes unsustainably, for the provision of infrastructure such as potable water supply, energy supply, and transportation. With constant increase in human population and rural-urban migration, the demand for environmental capital is on the rise [4,5]. Presently, an estimated half the world's population lives in urban areas [5,6]. The needs of these people for water, energy, transportation, and all that makes for life's comfort, constantly puts pressure on environmental capital. The competition for environmental capital is further illustrated when Africa's current population of slightly over a billion people (about 14% of the global population) is compared with the projected population of 1.8 billion people (or 20% of the projected global population) by 2050 [7–9]. This projected population explosion in Africa is attributable to the fact that Africa currently has the highest fertility (4.9 births per woman) and growth rates (2.2%) in the world [9]. Unfortunately, the geometric increase in the African population does not correspond with economic growth - a disparity which leads to unsustainable competition for environmental capital [10] (pp. 1563–1564). Using 2009 gross domestic product (GDP) estimates, 70% of all African countries had an average GDP of $1408 (purchasing power parity). The poverty illustrated by this figure becomes accentuated when contrasted with the highest GDP value of $91,379 per capita in the world from Qatar or the per capita GDPs of China and India with values of $6828 and $3296 despite high populations figures of 1.35 and 1.24 billion people respectively [10,11]. This relatively high level of economic poverty in Africa is reflected in every other aspect of human life, such as education, health, and the provision of food and shelter. Research has shown that public health is intricately linked to housing and related infrastructural facilities, such as water, sanitation, and energy [12–14], thus, highlighting the need to provide sustainable solutions to these problems. This study, therefore, assesses the ways through which basic human needs, such as water, sanitation, and energy, are currently being met in Africa, *vis-à-vis* the adverse effect that such practices have on humans and on the environment. Alternative approaches to tackling these problems are also discussed.

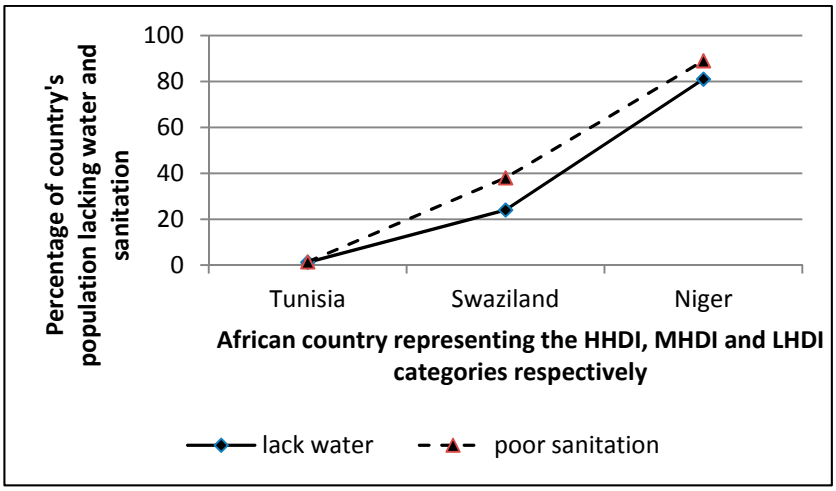
2 Environmental Challenges in Africa

2.1. Access to Potable Water and Sanitation

Water-related diseases have been identified as the leading cause of human mortality in the world [15,16]. About half of all hospitalized people in Africa were reported to be suffering from water or sanitation-related illnesses [15,17]. Challenges of access to potable water supply are more pronounced in rural areas, where women spend more than a quarter of the productive hours of each day on fetching water from sources, which may not be hygienic [18,19]. This is in contrast to the United Nations standard, which specified that each household should have water delivered to the occupants via *in situ* taps or via a water source that is within 100 meters or 5-minute total collection time [18–22].

An analysis of available data establishing the link between the level of water/sanitation crises and the level of human development in three selected African countries is shown in Figure 1. These countries are Tunisia, Swaziland, and Niger, representing the high human development index (HHDI), the medium human development index (MHDI) and the low human development index (LHDI) respectively [11,23,24]. The selection was based on the country having the poorest record in each category. While the population without access to water and sanitation in Tunisia is very low, it can be observed that the population of persons with problems of water and sanitation increased as the level of HDI decreased (Figure 1). The worst record was in the Niger Republic where 64.1% and 89.3% of its population lacked access to clean water and improved sanitation respectively.

Figure 1. Percentage population of selected country within each HDI category that lack access to clean water and sanitation [Source: [11] (pp. 143–145)].



Other African countries having acute water scarcity and sanitation records include Rwanda, Uganda, Democratic Republic of Congo (DRC), Ethiopia, Central African Republic, Angola, Burundi, Sierra Leone, and Zambia [11,25]. These are countries with more than half of the citizens living without sufficient water [11,26,27]. Some of the identified causes of water scarcity and sanitation problems in these African countries include:

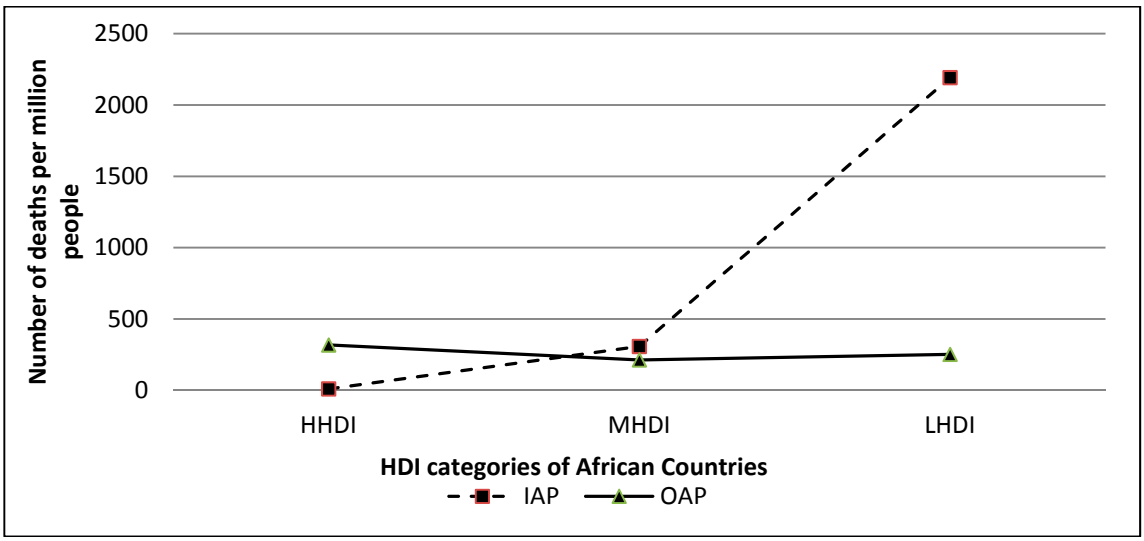
i. *Pollution and depletion of available resources through human activities*: about 80% of untreated domestic wastewater in Africa is released into surface water bodies, thus depleting available freshwater [28,29]. This is besides wastewater from agricultural and industrial activities [28] (pp. 36–38).
ii. *Insufficient finances*: development of water resources is capital intensive. It requires huge investments and subsequent maintenance efforts. Most African countries cannot afford the required investments, thus, limiting their water developmental projects and distribution capacities [29–31].
iii. *Water losses*: infrastructural facilities, such as pipelines are often vandalised by people seeking illegal connections to public water services. Such activities lead to water wastages and financial losses [26,27,32,33].

iv. *Weak water governing institutions*: some of the water corporations in African countries are operationally limited by factors such as lack of data, inept personnel, energy shortages, and limited finances [25,32,34,35].

2.2. Environmental Pollution and Public Health

Anthropogenic interferences such as agricultural, industrial, transportation and domestic activities have been instrumental to environmental pollution [36–38]. Of particular interest in this section is pollution affecting the atmosphere. Common health challenges arising from air pollution include pneumonia, tuberculosis, cataracts, upper air-way cancer and asthma, especially in children [39,40]. Air pollution can be classified into two categories, namely outdoor air pollution (OAP) and indoor air pollution (IAP). Air pollution arising from agricultural, industrial and transportation activities are outdoor pollutions. Studies have shown that OAP arising from vehicular emissions, which often contain carbon monoxide, sulphur dioxide, nitrous oxide, volatile organic compounds, and lead, are the highest sources of OAP [36,41–43]. Much of these emissions contribute to global warming. In addition, air pollution arising from domestic activities poses another set of challenges because they occur in relative isolation in the confines of individual households. Globally, an estimated 1.6 million people die annually from IAP, caused mainly by fumes generated by cooking activities or through smoke that is introduced into living quarters for the purpose of repelling mosquitoes [39,40,44]. About a quarter of global mortalities arising from IAP reportedly occur in Sub-Sahara Africa [40,44,45]. Analysis of available data on the link between the mortalities arising from air pollution and the level of human development among African countries is shown in Figure 2 [11] (pp. 150–153). Tunisia, Ghana and Niger had the highest mortalities arising from IAP in the HHDI, MHDI, and LHDI categories respectively, while Libya, Egypt, and Djibouti had the highest mortalities arising from OAP in the HHDI, MHDI, and LHDI categories respectively [11,45].

Figure 2. Deaths due to indoor and outdoor air pollution in 2004 [Source: [11] (pp. 150–153)].



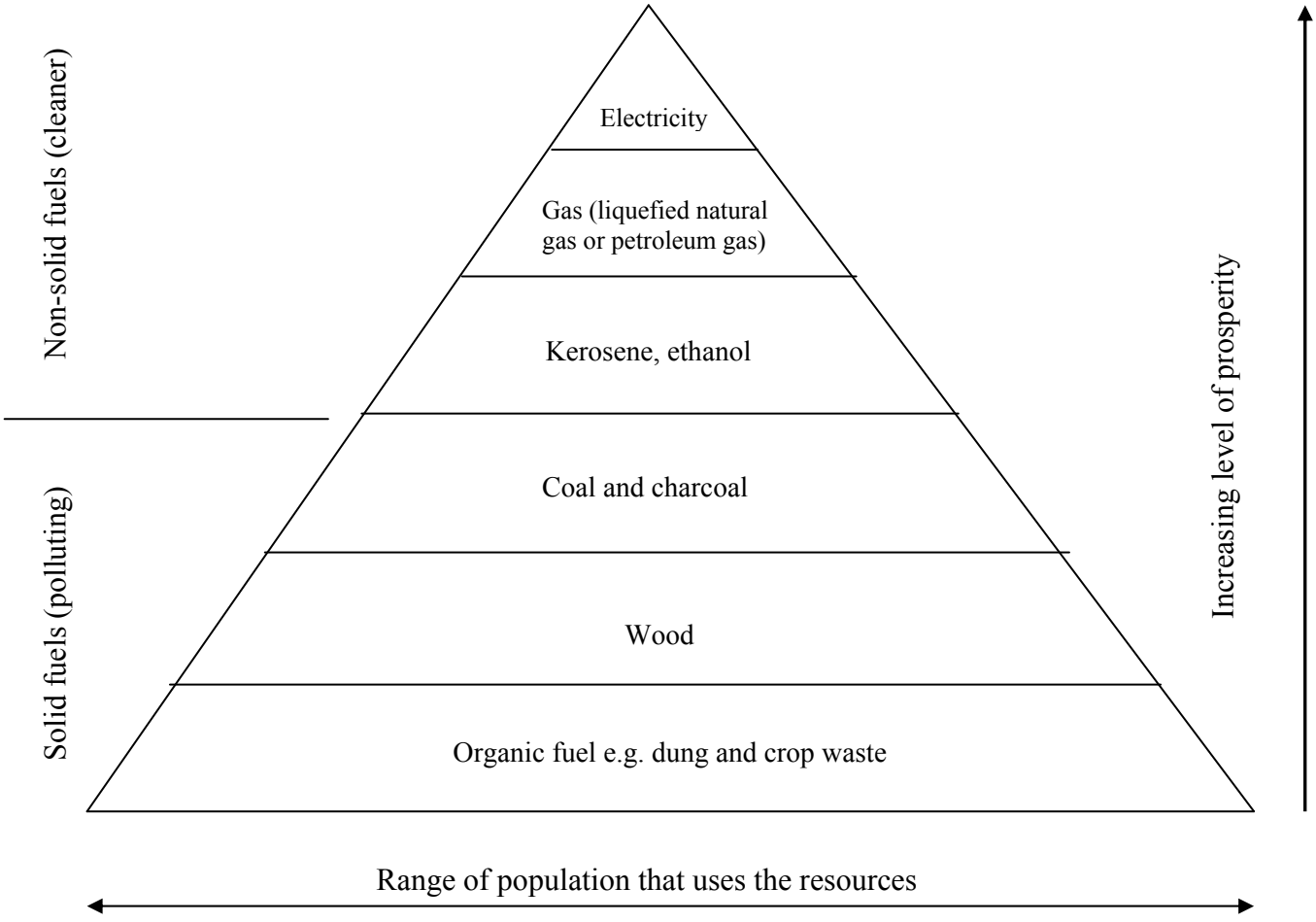
Although the total volume of OAP generated per annum exceeded IAP [36], more people reportedly died from IAP than OAP in the MHDI and LHDI categories. The higher mortality rate from IAP could be attributed to poor ventilation, because polluted air is not easily diffused in confined spaces. This was not the case, however, in the HHDI category (Figure 2) as there were more reported cases of death from OAP than IAP. Generally there were higher mortalities due to air pollution in the LHDI countries than the HHDI and MHDI categories, with the worst cases happening in Sierra Leone, Niger, Angola, Burundi, Guinea Bissau, Liberia, Democratic Republic of Congo, Rwanda, Mali, and Burkina Faso, respectively [11,46].

2.3. Sustainable Energy Development

There is a positive correlation between energy (generation and consumption) and human development as demonstrated by the fact that developed countries in North America (USA and Canada), European countries, and China, generated 24.6%, 27.5% and 17.2% respectively of the world's total installed energy capacity [47,48]. Comparatively, all the African countries generated just 2.66% of global energy produced in 2009 [48,49]. Energy generation in Africa is broadly classified into two types, based on the source. These sources are fossil fuel (oil, gas, and coal) and biomass. These energy sources are also geographically distributed. While fossil fuels are the predominant fuel sources in Northern and Southern Africa, Sub-Saharan Africa, where over 70% of the African population is concentrated, predominantly utilizes biomass [49–51]. Although fossil fuels are known to impact negatively on the environment, they are still the predominant global fuel sources as they constituted 56.5% of the total fuel consumed in the world as at 2009 [47,52,53]. Furthermore, methods of biomass usage in sub-Sahara Africa, such as open air burning, are detrimental to the environment [51]. Generally, solid fuel is the fuel of choice among most poor Sub-Sahara African people because it is cheap to procure and easy to use. However, solid fuels have the highest IAP potentials. A comparison of the choice of fuel by the population range of persons that use them is indicated in Figure 3. A further indication of income level and the choice of fuels are also shown in Figure 3.

It is estimated that three billion people used solid fuels as at 2005, and over 500 million of them resided in Africa [40,49,53]. This practice contributes directly to deforestation and consequently, climate change. It is also a cause of respiratory health challenges among its users. The energy sources indicated in the upper rung of the chart (Figure 3) are relatively cleaner but more expensive. At the apex of the chart is electricity, which is used by a relatively lower number of people although it is a relatively cleaner source of energy. Electricity, especially when generated by wind, solar or biogas energy, has lesser adverse effect on the environment. The total installed capacity for electricity generation in Africa as at 2009 was 3% of the global total. This has led to Africa becoming the continent with the highest energy intensity in the world [47,49]. This means that due to shortages in clean energy production, Africa's energy demand is being met in unsustainable ways such as biomass burning. Although Africa contributes nearly 16% of global fossil fuel production, neither the resource, nor the revenues from its sales has been translated into equivalent development for the continent [47,49]. Much of the revenue is lost due to misappropriation and mismanagement practices, which has further impoverished the African people [35,40,49,54–56].

Figure 3. Relationship between fuel sources and income level (Source: [40]).



3. Discussion

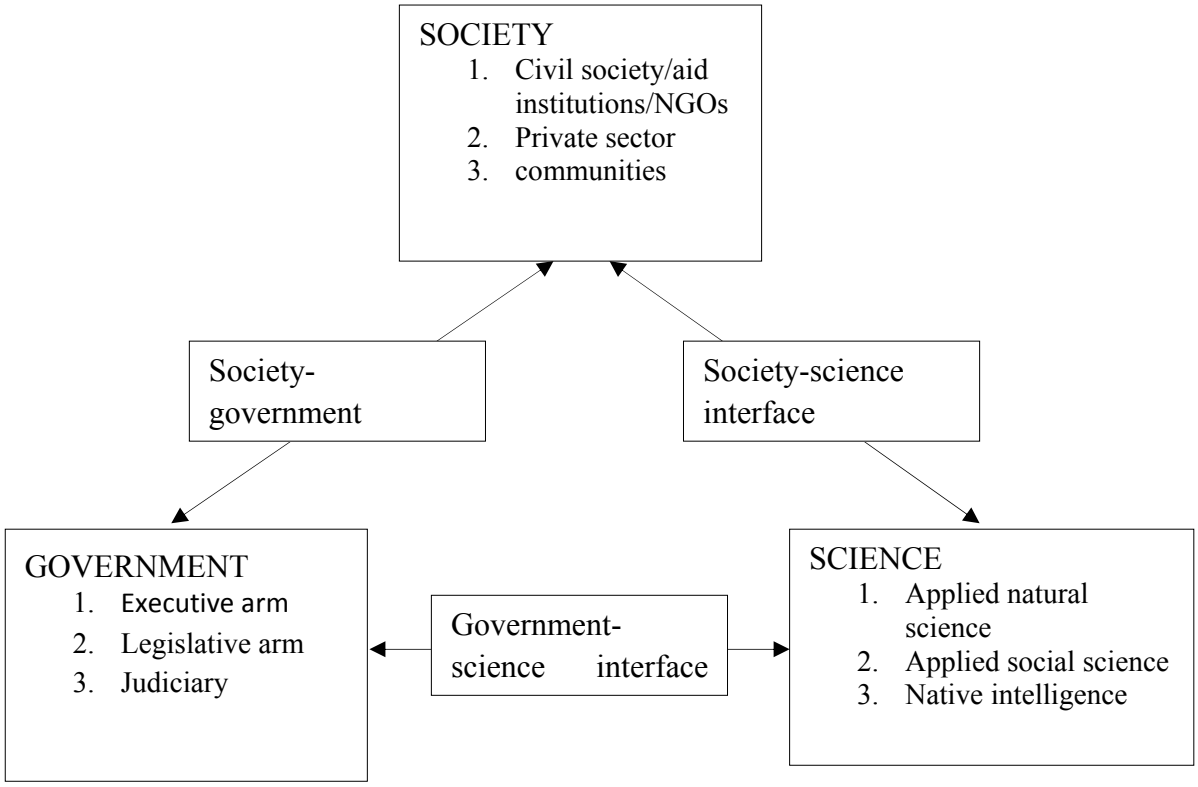
3.1. The Way Forward

The continued existence of man is dependent on the sustenance and manner of utilization of important natural resources. Discharging industrial and domestic wastewater into fresh water bodies, cutting down trees for biomass burning and depletion of the ozone layer with greenhouse gases are examples of the misuse of natural resources. This paradox therefore presents a situation where there is conflict in the need to use and also protect and conserve environmental capital. The solution to this problem could be found in a couple of concepts proposed by researchers. One of such concepts is the "soft path" approach to resource management. Originally, the concept of the "soft path" advocated the optimum management and proper use of water in contrast to the traditional "hard path" that advocated more supply of water through investment in physical infrastructure [30]. Soft path approach has been found to be very effective and applicable to other aspects of human endeavors. More results are being achieved at lesser cost since the paradigm shift is aimed at adjusting certain variables in what is presently available, rather than exploiting more of nature's resources [31] (p. 1).

Another concept, which is quite similar to the "soft path" approach, is the trialog model for resource governance. The latter was proposed by the Council for Scientific and Industrial Research (CSIR) in South Africa and it has received positive attention among applied and social scientists [57–60]. The

model proposes a democratic means for determining how natural resources should be used for the common good by identifying the three stakeholders and the interface that exists between them (Figure 4).

Figure 4. The trialog model [Source: [60] (p. 376)].



The trialog model is not farfetched from the better known public-private-partnership (PPP) concept which emphasizes the relationship between government and non-governmental organizations [55,61]. The main difference between PPP and trialog model, however, is that the trialog model emphasizes the role and importance of a third party (science) in the partnership [58,59]. Trialog model also emphasizes the importance of public perception as well as the promotion of democratic principles among the three parties [60] (pp. 375–377). Thus, trialog model is a simplified representation of the complex relationships between government, society and science. It advocates that government (as embodied by the executive, legislative, judicial, administrative, regulatory, and law enforcement organs) cannot effectively govern natural resources without scientific input or societal consent and cooperation. For instance, societal perception is a strong factor in the implementation of any policy. No matter how rational the scientific recommendation, society perception may make its implementation difficult or even impossible. In addition, organized science (natural and social) form the basis for informed decision taking. However, informal science or native intelligence has its usefulness, especially in the area of data gathering. Society has always been the custodian of natural resources and could offer its opinion when sought. This opinion when acted upon by organized science becomes a useful piece of information. The trialog model, though initially applied to water resource governance in South Africa, is also very relevant to governance issues concerning other natural resources such as ambient air and energy sources.

3.2. Global Case Studies

Some case studies that illustrate the application of both the trialog model and the soft path approach are found in different parts of the world. Conley and Dukkipati [61] (pp. 4–11) provide insight into the differing levels of cooperation between different European governments and non-governmental organizations (NGOs), who have a common goal of generating positive impact on the lives of ordinary people in different parts of the world. One such cooperation includes the collaboration of German and Netherland governments with the Bill and Melinda Gates foundation in solving health and environment related problems in developing countries through research as well as actionable programs. While the German government pledged €14 billion for the program, the Bill and Melinda Gates foundation pledged to match Germany's contribution towards the same program, thereby bringing the total budget for the program to €28 billion. These funds were disbursed to research based institutions, as well as indigenous non-governmental organizations in targeted countries for implementation. Regardless of the good intentions however, records indicate that there has been cases of failure of the program in some locations due to the singular fact that the members of the society who are meant to benefit from such people oriented programs distrusted the gestures and intents of the sponsors [62,63]. In Northern Nigeria, it was reported that such program was boycotted en-masse due to religious and cultural reasons [63] (p. 9). In Spain, it was also reported that the program which was developed to effectively manage the groundwater and ecosystem was met with conflicts because the stake holders were not carried along in the decision-making and planning phases of the program [58] (pp. 3389–3396). These problems could be avoided if social scientists/researchers could advise the sponsors on how best to implement such programs by considering social factors. Additionally, the government and civil societies could help to allay public fear through massive public campaigns and enlightenment programs. These examples illustrate the need for application of democratic principles, as espoused in the trialog model, in resource management and implementation. Conversely, some successes have been recorded in initiatives that involve the partnership between governments, NGOs, the society at large and researchers. It is reported that the highest successes in this regard is found in Netherlands and United Kingdom where the health, education, justice, transport, utilities, social housing and defense sectors of the economy have benefitted from public-private-society cooperation [55,64]. In Netherlands, the construction of new public wastewater management systems valued at €1.58 billion was conceded to a private firm for a period of 30 years by the government [55,65]. Concession means that government allows private firms to build, operate and transfer public utilities and/or services over a fixed period of time following which such facilities are handed back to the government. During the concession period, government retains ownership of such facilities or projects but its management and profit goes to the private organization during the concession period. In this arrangement, the government gets to provide better infrastructure and employment opportunities to its constituents, while saving public funds that could have been expended on such projects. The governments also serve as industry regulators and mediators between the private firms and society. The private firms make profit as a direct result of implementing cutting edge research/scientific innovations while the constituents/society get better services and an improved environment. In this sort of situation however, there is always the need for public enlightenment because the public usually has distrust for such programs due to the fact that concessions are often confused with privatizations [55] (p. 401). In the

energy sector, a private German firm known as EnviTec in collaboration with the India's Malavalli Power Plant Private Limited (MPPPL) has helped to provide electricity for over 180,000 Indian households using decentralized biogas technology [61] (p. 8).

Soft path approach to resource management is illustrated when efficient management of resources is favored above abstraction or exploration of more resources. As an example, researchers have found ways to reduce fossil fuel and water consumption through the use of biogas systems in Africa. Biogas Technologies West Africa Limited (BTWAL) utilized human wastes received in specially constructed toilets to generate biogas. The generated biogas is in turn used for electricity generation that provides lighting and drives the mechanical pumps used to supply water to the toilets [66,67]. In addition, nearly all the water used in the toilets are recovered and re-used within the toilets, thereby saving a lot of valuable fresh water. This technology has been implemented in schools, hospitals and military/Para-military barracks, in Ghana and Ivory Coast, thus, saving several million gallons of fresh water per annum. The gains of this technology are enormous considering the volume of money and other resources that are saved. For example, conventional toilets require sanitary vehicles for the evacuation of septic tanks when they are filled up. This becomes unnecessary since the wastes are now digested on-site. The cost of these trucks, which amounts to several hundreds of thousands of US dollars, is thus saved. Also, the need to constantly pipe water to the utilities is reduced due to the *in situ* recycle of water. Land conservation is another gain of this initiative considering that the digesters which are constructed using reinforced concrete are buried below the ground. This replaces the several square kilometers of land needed for sewage treatment at conventional waste treatment plants. Again the cost of energy is reduced when using fossil fuel (diesel) from between US$ 0.60–0.70 cents/kilowatt hour to between US$ 0.04–0.14 cents/kilowatt hour when using biogas [52,67].

In the water and food production sector, it is estimated that agriculture accounts for the use of 900 km^3 of water, which is 80% of all abstracted groundwater in the world [68]. Much of this water is lost to evaporation and ground seepage because most of the water is channeled through bare soil furrows, open canals and flooded plains. This wastage is being curtailed in countries such as Bangladesh, China, India, USA, Iran, and Pakistan where much irrigation activities are practiced through the use of precision water-saving technologies such as sprinkler and drip irrigation systems [68]. Thus, rather than investing in abstracting more groundwater—thereby jeopardizing ground water retaining structures/aquifers—more efficient use of already abstracted water is advocated. This approach, which ensures better crop yield, can be described as a soft-path approach to the management of groundwater resources. These examples demonstrate the wide applications of the trialog model and the soft path approach in resource management.

3.3. Local Case Study

Lagos State has been classified as the second fastest growing mega city in Africa and the seventh fastest growing city in the world [69,70]. With a current population of 21 million people and growth rate of 3.2%, the State has a population density of 20,000 person/km^2 in its built-up areas [2,71]. One of the challenges created in areas with high population density is transportation problems. In the first instance, constructing new roads or expanding existing roads can be very costly. In the second instance, the existing land constraint situation could adversely affect other aspects of the society if

more road networks are constructed. Therefore, the appropriate management of existing infrastructure becomes an attractive alternative. This is known as the soft path approach to resource management. To solve the transportation problem, the Lagos Bus Rapid Transport (BRT) system was created in 2008. Although it is not the first BRT model in the world, the Lagos BRT is unique in that it was the cheapest in terms of implementation when all other factors such as population served and cost of implementation per kilometre are taken into consideration [72–74]. Details of the project included the purchase of 220 midi-buses, construction of bus parks/boarding stations, partitioning of existing roads using 400 mm high kerbs and/or paint markings for the BRT routes. At a total implementation cost of $37.4 million, this represents a fraction of what would have been needed to construct new road networks. Today, the BRT project transports 60 million passengers per annum and is self sustaining [72,74]. A survey revealed that 65% of those who benefitted from the Lagos BRT in 2009 had no personal vehicles, while 25% (1.5 million people) gave up the use of their cars to take advantage of the facility [74]. This translates into a lot of energy savings as well as prevention of vehicular emissions which could have been dispersed into the atmosphere. Further, the Lagos BRT succeeded because of the collaboration between all stakeholders (the government, transport consultants (researchers) and the society). The government provides the regulations through its agency, Lagos metropolitan area transport management agency, LAMATA. Government also procured 120 buses which it leased to private operators. The remaining 100 buses were procured directly by private operators. Other benefits provided by the BRT project included a 30% reduction in fares in comparison to existing transport schemes in the State. There was also a 40% and 35% reduction in travel time and queuing times respectively, besides safety and comfort [74]. A BRT television show with a weekly audience of five million people is broadcasted twice weekly to inform the public and to provide a platform for a much needed feedback system. This example further illustrates the dynamics of the trialog model.

3.4. Stakeholder Responsibilities

The presented case studies have highlighted the responsibilities of different parties in the trialog model. It has been shown that government can gain a great deal by partnering with research institutions/scientists and other members of society (the public, NGOs and Civil Societies) in solving society's problems. Each partner within the model, however, has roles and responsibilities. The government ought to provide regulatory and security services, while the scientific institutions/researchers have the responsibility of fashioning out solutions and serving in advisory capacity to both government and society. The private sector and NGOs (as part of society), in many cases, also provide infrastructural services for their employees and communities in the areas in which they operate. They could also serve as conduits through which government educates and communicates its policies on water, sanitation and energy to the larger society. On the other hand, the private sector can also be culpable in the degradation of the environment. Although it is nearly impossible not to generate waste in the process of production, the impact of such generated wastes on the environment can be minimized through appropriate law enforcement guided by advisory input from the scientific community. In addition, civil societies and organized unions could serve as checks on the activities of the private sector by making reports of observed pollution activities to the relevant government regulatory agencies.

4. Conclusions

This study has demonstrated that thousands of lives are being adversely affected as a direct result of environmental degradation arising from unsustainable development practices in some parts of Africa. While human development is highly dependent on the use of natural resources, human survival is much more dependent on the practice of sustainable and responsible resource utilization. A proper understanding of the concept of the trialog model as well as the "soft path" approach can help all stakeholders to effectively play their role in the drive towards sustainable human development. These two concepts advocate smooth working relationships among stakeholders as well as the appropriate use and management of resources rather than exploitation of more resources. The trialog model identifies government's primary role as regulatory. It also identifies the scientific community as the advisory party responsible for developing ways through which resources can be optimally exploited and appropriated for human use without repercussions on either humans or the environment. The third party in the trialog model (society) is the main beneficiary, as well as primary custodian of environmental capital. Although the proponents of the trialog model have adapted it to water resource management, it is the position of this study that the merits of the model could be extended to the governance of all other resources such as ambient air, forests, food and energy resources.

Furthermore, due to increasing developmental activities, as well as Africa's reputation, as the continent with the highest energy intensity, Africa has the potential of becoming a major contributor to global warming. Although Africa contributed just 3.6% to global carbon emission as at 2008 [48], the situation could worsen rapidly if adequate measures are not set in motion as early as possible. Therefore, research and development effort should be directed at creating alternative sources to replace the use fossil and solid fuels. Potential energy sources that could be explored for use in Africa include wind, geothermal, solar, hydropower and biogas. In the short-term, however, private sector operators of industries which currently generate more power than they can consume should be encouraged to sell such excess energy to their host communities. In addition, favorable policies should be offered as incentives to encourage private sector entrepreneurs who wish to invest in environmentally-friendly energy production. This could help reduce the number of people who depend on solid fuel as energy source.

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Author Contributions

This research was designed by David O. Omole and the paper was jointly written by David O. Omole and Julius M. Ndambuki.

Conflicts of Interest

The authors declare no conflict of interest.

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