Population, Development, and Waste Management in Botswana: Conceptual and Policy Implications for Climate Change

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ABSTRACT / Based on government and other relevant documentation, this paper explores the conceptual linkage between population, development, and waste management in Botswana and the implications of this relationship for global climate change. Population is increasing, albeit at a decreasing rate. Spatially, the population is becoming more and more concentrated as the rates and level of urbanization increase. Economic growth has remained consistently high. The combined effect of population dynamics and economic development are having a noticeable imprint on the environment in the form of increased waste generation. Poor waste management poses a real threat to environmental sustainability in general and climate change in particular because of inadequate technology, weak institutional mechanisms to enforce regulations, and low levels of sensitization among the public to deal with the problem. Mitigation measures are suggested to minimize the negative effects of waste management on climate change.

The linkages between population, development and environment have been articulated through the Ehrlich and Holdren model (1971).

$$I = PAT \qquad (1)$$

From a national perspective, this would imply that the human environmental impact (I), in this case waste generation, depends on subnational population (*P*), in terms of its size, growth, and concentration; its affluence (*A*); and the methods (*T*) it employs to obtain its livelihood and dispose of its consumed products.

The practical implication would be that greater environmental impact would accompany a large, rapidly growing, and relatively highly concentrated population. In this context, Ajaegbu (1985) has remarked as follows with regard to sub-Sahara Africa: "...as human population concentrations increase, the effects of the imbalance in the population–environment interrelationships become more noticeable and worrying." One of the most worrying symptoms of such a negative population–environment linkage is poor waste management.

Affluent communities tend to consume more resources and dispose of more waste. According to Kgathi and Bolaane, the World Bank (1999) report suggests that there is a positive relationship between rising incomes and generation of municipal solid waste (Kgathi and Bolaane 2001). The role of the technology factor tends to be less clear. Marginalized communities tend to overexploit their environments, using premodern techniques, just to survive. Turner and others have suggested that the intensity of environmental change is more strongly related to poverty, rather than affluence, particularly in developing countries (Turner and others 1995). The same observation has been alluded to by Leonard and others (1989).

Commoner has argued, however, that in the Ehrlich and Holdren model, the needs of population are met by economic development, which in turn causes environmental degradation, thus:

$$\text{Population} \rightarrow \text{Economic development} \rightarrow \text{Environmental degradation}$$

If this relationship holds, environmental quality can be sustained only by regulating either economic development or population dynamics—or both. The weakness in this approach is that it omits the basic human action that is the necessary precursor to economic development: the creation of the means of producing the goods that generate wealth. It is this intermediary function—the technology of production—that leads, in parallel, to both economic development and environmental degradation. That is,

$$\text{Population} \Rightarrow \begin{array}{l}\text{Production} \rightarrow \text{Economic development} \\ \text{Technology} \rightarrow \text{Environmental degradation}\end{array}$$

KEY WORDS: Botswana; Waste management; Greenhouse gas emissions; Climate change

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Of the three hypothetical determinants of environmental degradation, Raskin (1995) and Commoner (1991) have argued that the technological factor is the most significant. To illustrate that point, Commoner refers to what happened in the United States between 1970 and 1980. The population (*P*) increased by 19% and the number of automobile miles driven per person (*A*) increased by 45%; yet carbon dioxide emission declined by 42%. From that perspective, he maintained that the Ehrlich model should take the form of a mathematical identity:

$$\text{Pollution} = \text{Population} \times \text{good/population} \times \text{pollution/good} \quad (2)$$

In this case affluence is stated as the per capita consumption (or production) of a particular good, and the effect of the technology factor is expressed as the amount of pollution imposed, upon the environment, per unit of production of that good.

Arguments have been made about the appropriateness of the identity in its static form. Therefore in order to accommodate change, over time *t*, the above equation has been expressed as follows:

$$1 + \Delta\text{pol} = 1 + \Delta\text{pop} \times (1 + \Delta\text{good})/ \cdot(1 + \Delta\text{pop}) \times (1 + \Delta\text{pol})/(1 + \Delta\text{good}) \quad (3)$$

where Δpop is change in population size, Δgood is change in the amount of a given good produced or consumed, and Δpol is change in the amount of pollution generated when the good is produced or consumed.

The overall implication, therefore, is that for the developing countries, where technology is still relatively crude, the environmental impact of waste and pollution will be difficult to deal with in the face of increasing population and affluence. Available evidence suggests that developed countries have been able to reduced the amount of waste produced per unit output (Pearce and Watford 1994). The fact that developed countries remain responsible for the bulk of global pollution therefore reflects the failure of their policy instruments rather than lack of the requisite technology.

Whereas human settlements in developed countries appear to have the necessary technological ability to manage their waste, this is not the case for the developing nations where municipal authorities lack sufficient financial, technical, technological, and human capacity and expertise to deal effectively and in a timely way with the solid and liquid waste generated (Gwebu 1997, Hagos 1997, Mekonnen 1997, Songsore 1997). Such a situation poses a serious threat to the environment.

Apart from the technological, affluence, and population size/distribution variables, a more complete explanation of environmental impact factors should incorporate cognitive, perceptual, regulatory, and economic factors in underdeveloped countries. There are several reasons for this. The level of awareness by the general public of the significance and implications of unsustainable waste management is relatively low. The urban environment is regarded as an open access domain over whose aesthetics nobody is accountable, except urban management. Enforcement of statutes governing sustainable waste management is difficult due to lack of cooperation from both the formal and informal sectors and the lack of capacity to enforce such legislation. The general populace has come to live by a dependency-culture syndrome of free handouts from central government including provision of services for waste management. Reduction of subsidies and provision of services at economic rates could provoke politically unpalatable reactions. There also appears to be little corporate responsibility towards the promotion of environmental sustainability.

Population Size, Distribution, Affluence, and Waste Occurrence Patterns in Botswana

Population Size and Distribution

The latest census results show a decline in the population growth rate at 2.4% during the 1991–2001 period, compared with 3.5% between 1981 and 1991 (CSO 2001). This reflects the combined effects of family planning and the impact of the AIDS pandemic. Even under the worst scenario, the population is nonetheless projected to increase at about 1.2%/yr for the next two to three decades. This rate is still relatively high when compared with societies that have reached either their replacement levels (zero or negative population growth).

Currently, the population is about 1.7 million, which gives a crude density of about 3.2/sq km. This, however, is misleading because the population is unevenly distributed. Currently, the concentration ratio is 42% which implies that 42% of the national population would have to be redistributed in order to attain an even distribution. The highest densities tend to occur in the urban centers, with Gaborone, Francistown, and Selebi Phikwe having populations in excess of 1000/km^2.

Evidence from national migration surveys and national census data supports the view that Botswana is

Table 1. Urbanization in Botswana 1971–2000

Year	1971	1981	1991	1997	2000
% Urban	9.0	17.7	45.7	48.7	51.6

Source: CSO (1994).

going through what Zelinsky characterized as the early transitional phase, in his four-stage mobility transitional model (Zelinsky 1971). There is massive migration from the countryside to the towns, especially the largest ones.

Although Botswana is likely to experience relatively little national population growth in the next few decades, urbanization will continue, with approximately 60% of the population expected to be urban by 2021 (Sanderson and others 2001). Even though the 2001 census shows a relatively lower urbanization rate for modern towns and cities during the 1991–2001 intercensal period, their satellite/dormitory urban villages recorded phenomenal growth (CSO 2001).

Before independence, in 1966, less than 5% of the national population was classified as urban. That urbanization pattern has been increasing very rapidly since the mid-1970s, as can be seen from Table 1.

These trends show a rapid rise in urbanization and are mostly attributable to rapid rural to urban migration and an increase in the number of places classified as urban. It is noted in National Development Plan 8 that with the rapid expansion of economic activities in the mid-1970s and the 1980s, the pattern of settlement has changed rapidly. A growing concentration of the population around five major regions in the country has been observed. The concentration clusters include settlements in the Gaborone, Serowe/Palapye, Francistown, Selebi-Phikwe and Maun catchment areas. Population growth and concentration have been associated with an increase in waste. Table 2 shows the trend for Gaborone, the country's largest urban center.

Geographical Distribution of Affluence

Sanderson and others have noted that in spite of the HIV/AIDS scourge, Botswana has been experiencing exceptional economic growth. Over the last decade economic growth (adjusted for inflation) has averaged 5.5%/yr and there is no indication of a near-term economic collapse (Sanderson and others 2001). This rapid economic growth has been accompanied by an excessive generation of waste. Emissions of GHGs from waste are therefore expected to increase correspondingly for the foreseeable future. This is because, apart from its distinctive growth rate, the country enjoys the highest disposable income in sub-Sahara Africa, with a GNP per capita of US$3200.

The 1993/94 Household Income and Expenditure Survey (HIES) results, however, show that Botswana's income is highly skewed. Poverty is higher and more severe in rural areas. The distribution of poverty by geographical area indicates that the incidence and severity of poverty is highest in the sparsely populated western and more remote parts of the country. A recent study on poverty alleviation showed that 55% of the rural population was living in income poverty, compared with 29% in urban areas. The uneven spatial distribution of wealth has direct implications for the geographical occurrence of waste.

Spatial Patterns of Waste Occurrence

The National Conservation Strategy document (1988) notes that pollution is increasing in the country, especially around the large settlements. It identifies a variety of sources of pollution particularly littering, dumping, and unsightly stock piling, and that pollution manifests both a lack of civic awareness and the absence of effective incentives and controls which could prevent pollution.

Available statistics from the 1998 edition of Botswana's Strategy for Waste Management illustrate the differences in mean per capita waste generation between urban and rural areas (Table 3). The figures seem to suggest that the urban areas, because of their higher and more concentrated population and greater consumption patterns, tend to generate more waste per capita than the rural areas.

Types and Quantities of Waste Products

Information on quantities of waste generated in Botswana has been very limited in the past. Only recently have environmental statistics been compiled (CSO 2000) (Table 4). Solid urban industrial waste is made up of 38.3% wearing apparel remnants, 23.7% building material refuse, and 15.9% grain milling. Fifty-seven percent of liquid industrial waste was from beer, wines, and spirits manufacture and 11.1% from printing and publishing.

A survey of rural villages showed that plastics and paper constituted about 25% of the waste, by mass, followed by glass (24.5%) and metal (21%). In the major villages, construction waste and organic matter were the major types: 93% of landfilled waste in Gaborone, Botswana's largest urban center, is made up of refuse and garden trimmings.

Table 2. Waste quantities (tonnes) in Gaborone 1993/94–1996

	1993/94	1994	1995	1996
Landfill cum.total	221 892	516 238	661 170	832 995

Source: Gaborone City Council, Department of Environmental Health 1996 annual report.

Table 3. Mean per capita waste generation by locality

	Waste disposed (m^3/person/yr)	Waste disposed (kg/person/day)
Urban	2.32	1.32
Rural	0.36	0.20

Source: CSO (2000, Table 17.2).

Table 4. Estimates of Botswana's annual waste

Waste type	Quantity
Selected solid waste (tonnes/yr)	
Solid waste (excludes mine waste) at landfill	270,425
Solid hazardous waste	1,560
Hazardous clinical waste	2,500
Scrap metal waste	20,000
Household waste	250,000
Miscellaneous waste	
Liquid hazardous waste (000m^3)	34,610
Tires (number)	90,651
Household dry cell batteries (number)	24,000
Lead acid batteries (number)	46,000
Oil waste (000 litres annually)	5,600

Source: CSO (2000, Table 17.1).

Waste Management Practices and Implications for Climate Change

Waste management is a new concept in Botswana as well as the entire southern Africa subregion, except the Republic of South Africa and Zimbabwe. Waste management is the systematic control of all unwanted by-products of human activities. The internationally accepted conceptual framework for such control takes the form of the following hierarchy:

Waste reduction
↓
Reuse/recycle
↓
Treatment
↓
Safe landfill disposal

The top priority involves minimizing waste output from industrial, commercial, and domestic sources, reuse of some of the collected waste products after their primary use, and recycling/remanufacturing items from waste. Hazardous waste must be treated to eliminate its toxicity and harmfulness before disposal. Finally, unrecyclable and/or unusable waste has to be disposed of in a nonhazardous environmentally friendly manner.

Solid waste may be disposed of through land filling, in either uncontrolled or engineered landfills; incineration; crude burning; or open dumping. In Botswana the Waste Management Strategy and Act and landfill guidelines underline the importance of landfilling. There are over 175 waste disposal sites throughout Botswana. Of these, only two are properly engineered landfills, with the aim of conserving and protecting groundwater sources. The second one has been reduced to an ordinary waste dump due to poor management and maintenance (Simon and Phatshwe 1999).

Landfills are the ultimate repositories of waste for urban areas and certain urban villages. The most important biogas or landfill gas produced is CH_4. Globally, annual emissions from landfills are estimated at 6%–20% of total anthropogemic sources (UNEP, WHO 1996). Recently, increasing attention has been focused on the role of methane in global atmospheric climate change. One unit of methane has a global warming potential of 21 computed for a 100-year horizon or 56 computed for 20 years. There are several important factors that influence the generation of methane from the landfill disposal of solid waste in Botswana. Modern urban sanitary landfills are designed on the basis of the stipulated guidelines (NCSA 1997). They are lined before receiving waste, with adequate provisions for the safe control and removal of leachate. No provision has been made for the removal of methane, however. Apart from generating CH_4, landfills also produce substantial amounts of CO_2 and nonmethane volatile organic compounds (NMVOCs).

The other challenges to landfill development and management include (Phatshwe and Simon undated) lack of financial resources, lack of skilled manpower, providing landfills for a sparsely distributed population, and sandy soils that limit the local availability of lining and cover material. Open dumping and unsupervised incineration of organic waste occurs in the villages and in low-income urban neighbourhoods; yet organic waste remains the main source of greenhouse gases (GHGs) from incineration and CH_4 biogas emissions. Waste collection facilities are inadequate except in the urban upper income residential neighborhoods. What is not collected is usually dumped and burned in the open, thus releasing CO and CO_2. Solid waste in rural areas, low-income urban neighborhoods, and country-wide medical waste are disposed of by inefficient incineration methods (CSO 2000). This adds to CO and CO_2 emissions.

A large fraction of the carbon from waste such as paper and food waste is derived from biomass raw materials that are eventually replaced by regrowth on an annual basis. Under conditions of sustainable biomass regeneration, these emissions are not considered as net anthropogenic CO_2 emissions. However, other solid waste products based on fossil fuels such as plastics, and petroleum products do release net CO_2 emissions apart from N_2O, NO_x, CO, CH_4, and NMVOCs.

Although efforts are being made to recycle plastics and waste paper, there are currently no economic measures in force to discourage industrial and consumer use of plastic products in Botswana. There is some recycling of aluminum beverage cans, plastic and waste paper in the country (CSO 2000, pp. 203–204). There is also limited reuse of glass bottles and paper cartons. At the moment, the development of energy conversion methods is underexploited, being confined to a limited number of biodigesters or the burning of beer cartons for heating water (Kgathi 1992).

Waste reuse of inorganic substances is now being practiced. However, this has as yet to be practiced on a large scale in the case of organic waste products, which are a potential source of CO and CO_2.

Some of the medical waste is incinerated. This is, however, improperly done due to lack of trained personnel and may be responsible for incomplete and partial combustion of such waste and the release of GHGs.

Apart from solid waste, human settlements generate liquid waste products. In the major settlements, liquid waste is accumulated at treatment plants (CSO 2000). Anaerobic methods are used to process the highly organic waste from municipal sewage and from food processing and other industrial facilities.

The treatment of wastewater and sludge under anaerobic conditions results in CH_4 emissions. Globally CH_4 from wastewater treatment (WWT) represents 8%–11% of the total annual anthropogenic emissions (IPCC 1996). Botswana's contribution is a mere 2.05 Gg. Other gases from WWT normally include N_2O and NMVOCs but they seem to be insignificant in Botswana, whose main source of N_2O includes solid waste landfills and pit latrines (Table 5). Studies from elsewhere, however, indicate that open pits and latrine systems do emit considerable amounts of CH_4, under high temperatures and long retention times. This needs to be investigated in Botswana where these conditions apply.

Table 5. GHGs from solid and liquid wastes

GHG sources	CH_4	N_2O	CO_2 equiv. (Gg)
Solid waste landfills	7,83	0,02	164,35
Waste water	0,10	-	2,05
Pit latrines		0,017	5,35

Source: Adapted from Zhou (1999, Table 3.1.2).

To summarize, the disposal and treatment of both solid and liquid industrial and municipal waste produces emission of the most important GHGs, namely CH_4, CO, CO_2, NO_x, N_2O, and nonmethane volatile organic compounds (IPCC 1996). Landfills, waste incinerators, wastewater treatment plants and pit latrines are the main sources of some of these gases in Botswana (Table 5).

Minimizing treating, and properly disposing of waste from domestic household, economic, and industrial sectors should correspondingly minimize the amount of waste generated and the associated GHG emissions. However, the technology to do this remains inadequate. There is also a need to broaden the scope of factors accounting for the unsustainable waste management process to include perceptual, regulatory, and economic instruments.

Conclusions and Recommendations

This paper uses the broad population, development, and environment conceptual framework to explain the spatial occurrence of waste. Population growth and the increasing spatial concentration of the population in large settlements is likely continue to place a heavy demand for facilities for handling the generated waste in Botswana. The failure to manage waste properly is due in part to the lack of adequate financial, technical, technological, and human resources to deal with the problem. This poses serious implications for GHG emissions.

The ultimate solution to the GHG emission problem from waste will entail more than a technological fix. It will require a strategic mix of approaches involving technological, regulatory, sensitization, and market-based incentives (Kgathi and Bolaane 2001).

Botswana's experience with waste management is relatively very recent. The country has achieved some appreciable level of success in its efforts to manage waste (Phatshwe and Simon nodate). The present policy framework is flexible enough to handle climate change issues arising from waste. The nation could nonetheless learn from both the developed countries and experiences drawn from its SADC neighbors such as South Africa and Zimbabwe. Research and development programs designed to initiate and adapt environmentally friendly approaches of waste management should therefore be given adequate support.

The provision of proper landfills for waste disposal will minimize environmental and groundwater pollution, but these structures seem to have not been designed to handle the CH_4 which will be generated. Landfills will have to be engineered to permit the harvesting of methane, which constitutes an ideal alternative energy source to conventional fossil fuels (Gwebu 2001). The problems surrounding the management of landfills will have to be addressed.

Proper incineration of waste should be encouraged by installing high-temperature incinerators. These will minimize CO emissions if operated by qualified personnel. Combustible waste can also be utilized to supply a viable energy source from the heat produced by incinerators that are currently used to reduce the volume of waste. Examples of such energy being converted to thermal electricity include the Edmonton incinerator in East London and Tronville-en-Barrois in northeast France (Marrion 1994). Composting could also minimize GHG emissions resulting from the open burning of organic matter.

Wastewater treatment (WWT) entails pretreatment of wastewater to reduce biochemical oxygen demand. Municipal sewage works in Britain, for example, typically produce biogas consisting of 70% methane and 30% carbon dioxide and sludge (Marrion 1994). Flaring of methane is globally beneficial because methane is a much more potent trapper of heat in the atmosphere than the equivalent carbon dioxide produced by its combustion (Marrion 1994, p. 290). In China, several million small-scale digesters have been constructed to tap such biogas fuel for local domestic cooking and lighting (Marrion 1994, p. 296) Sludge is useful as fertilizer. The nation could draw useful lessons from these examples.

Monitoring of N_2O from pit latrines remains an essential requirement to meet United Nations Framework Convention on Climate Change (UNFCCC) stipulations.

Sensitization of communities to handle their waste properly by nongovernmental organizations (NGOs) and the Botswana Defence Force (BDF), through formal education and Information Education and Communication (IEC) programs of the potentially negative effects of GHG emissions on the environment, is a step in the right direction. Government provision of services on a cost-recovery basis is a move in the right direction as it has the potential of reducing the amount of waste liable to crude burning in low-income neighborhoods.

Economic costs need to be factored into the production of waste through the polluter-pays principle. Industries and consumers must bear the full cost in order to minimize the production and use of for example plastic and paper products which are later on inefficiently incinerated.

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