Botswana's Future

Modeling Population and Sustainable Development Challenges in the Era of HIV/AIDS

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Executive Summary
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Foreword

Science, like government, tends to be compartmentalized into disciplines. A division of labor is useful because it allows for in-depth expertise and efficient action. The only problem is that the real world is not compartmentalized, and changes in population, development, and environment are interwoven. Over a short time horizon these intersectoral dependencies may not be very important, but over a long planning horizon it becomes imperative to address a country's future in a comprehensive interdisciplinary and interministerial manner.

This type of comprehensive analysis of long-term future options has been the explicit goal of this project, which combines more traditional descriptive analysis with interactive computer modeling. The project has been carried out in the context of a population–development–environment (PDE) framework of analysis, developed at IIASA over the past decade and applied to earlier case studies, with close substantive collaboration between IIASA and the national partner institution. Such collaboration between national and international experts, which lies at the heart of the PDE approach, also proved to be a highly successful strategy in this case.

This Executive Summary is only one output from the project. Major scientific books documenting the work in detail will soon be available, along with a CD-ROM and a Web site (www.iiasa.ac.at/Research/POP/pde/) with the full computer model and other important documentation that will allow the user to personally evaluate alternative strategies and scenarios toward the country's sustainable future development.

It is our hope that these findings will be discussed in both academic and political circles at the national and international levels, and that this discussion may lead to closer collaboration among countries in the Southern African region on these vital longer-term challenges.

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No project of this magnitude happens without the help of many people. Marilyn Brandl helped organize the work and cheerfully typed, edited, and coordinated many versions of this document. Isolde Prommer produced the CD-ROM that contains the models underlying the findings presented here. She also played a crucial role in coordinating the efforts of project participants, who were often on different continents, and in arranging the conference in Windhoek on March 14, 2001, where the results of the research were presented. Alyssa Holt did the research underlying our findings on water demand. David Yates helped with the design and parameterization of the water supply model. Annababette Wils helped program the Botswana Demographic Model. Wolfgang Lutz, the leader of the Population Project at IIASA, provided encouragement and insightful comments throughout the process. When our focus wavered, he always brought us back to reality.

We give special thanks to Kuberin Packirisamy, who, despite personal tragedy, did a brilliant job of programming the core of the Botswana Demographic Model. This project would not have been the same without his untiring work.

Main Findings

1. Botswana is likely to have little or no population growth for the next two decades. If the current situation continues without changes in behavior or the generalized use of medication to lengthen the life span of those with HIV, Botswana's population will be lower in 2021 than it is today. In our base case scenario, which assumes a significant amount of behavioral change, Botswana's population would be roughly the same size in 2021 as it is in 2001. In the extremely unlikely event that a perfectly effective vaccine is found, which eliminates all new cases of HIV beginning next year (2002), Botswana's population would be about 20% higher in 2021 than it is today.
2. The data collected by the Sentinel Surveillance Surveys are inadequate, especially given the magnitude of the suffering and deaths caused by HIV/AIDS. Survey sizes are small, not representative, and contain no descriptive information about the women except their ages. No usable data exist for men. Without better data, it will be difficult or impossible to distinguish interventions that only appear to work from those that are actually effective. The result could easily be poorer policies and greater suffering. Improvement of the Sentinel Surveillance Surveys should be a high priority.
3. Although Botswana is likely to have little population growth in the next two decades, urbanization will continue. Roughly 60% of Batswana will live in urban areas in 2021, compared with around 40% today. This implies that there will be a significant decline in Botswana's rural population. More and more, the rural population will consist of the elderly and young AIDS orphans. The rural labor force will decline more rapidly than the rural population. In 2021, we expect that Gaborone will have around 40% more people than it has today. Providing services to an increasing urban population will remain a challenge to the Government of Botswana in the decades to come.
4. Botswana is in the midst of a rapid education transition as a result of past and current policies aimed at increasing educational attainment levels.

HIV/AIDS, even though it kills people in their most productive years, will not reverse this transition. There will be a substantial increase in the number of people in the labor force with a secondary school education or above, and an absolute decrease in the number of people with a primary school education or less. This revolution in educational structure will have important effects on the economy.

5. Deaths from HIV/AIDS will change the age structure of the adult population.
6. Botswana has experienced exceptional economic growth. Over the last decade economic growth (adjusted for inflation) has averaged around 5.5% per year. In our base scenario, that growth rate falls somewhat by 2021. There is no suggestion of a near-term economic catastrophe.
7. The effects of changes in the trade regime by themselves will increase Botswana's rate of economic growth, even if they do not change its rate of export growth, because the stimulating effects of lower import prices on the domestic economy are more important than their effects on government revenues. Because the changes happen only gradually, the stimulating effects become stronger over time.
8. The cost of HIV/AIDS medication is falling rapidly. Reductions in the price of these medications have now made their use economically feasible in Botswana. A widespread campaign promoting the use of HIV/AIDS medication would cost between 1.4% and 2.5% of the Government's budget by 2011 at today's (reduced) prices. This corresponds to between 9% and 16% of the Government's surplus.
9. In the past, high levels of unemployment and underemployment have been problems. This will change over the next two decades. Although it seems like wishful thinking today, an important labor market concern will become the short supply of unskilled labor.
10. Without additional conservation measures and water infrastructure, Botswana will experience water stress in each of its three major geographic regions within the next 20 years as a result of urbanization and economic growth.
11. Gaborone will face water resource management challenges over the next 20 years that must be met if water demands are not to exceed water supplies. If appropriate conservation measures are adopted, Gaborone will not need Phase II of the North South Carrier Water Project.
12. Different climate change models yield different implications for Botswana's future which range from a slight decrease in water stress to a significant increase in water stress. Even given the uncertainties, it would be prudent to plan now for additional water scarcity.
13. Increased groundwater use may not be sustainable.

Introduction

In 1997, the International Institute for Applied Systems Analysis (IIASA, Laxenburg, Austria) began a research project, funded by the European Union, on future population, development, and environment interactions in Botswana, Mozambique, and Namibia.

All the results presented here are based on detailed computer simulation models calibrated to data from the 1990s. These models and information on how to run them are available on CD-ROM and on IIASA's Web site: www.iiasa.ac.at/Research/POP/pde/. This work is the continuation of a series of projects on population, development, and environment interactions that includes studies of Mauritius, Cape Verde, and the Yucatán peninsula of Mexico. Parallel Executive Summaries have been prepared for Mozambique and Namibia. A volume comparing Botswana and Namibia and a separate volume on Mozambique are in preparation. Working drafts of the chapters of those volumes are posted on the IIASA Web site as they become available: www.iiasa.ac.at/Research/POP/.

Our philosophy has been much the same throughout all our projects. We create models that are detailed, stay close to the data, and integrate population, development, and the environment. This Executive Summary presents our main findings for Botswana.

One element dominates current discussions of Botswana's future, the problem of HIV/AIDS. Currently, Botswana has one of the highest HIV/AIDS prevalence rates in the world. We estimate that during the period from 1993 through 2001 there were around 130,000 deaths from HIV/AIDS. In 2001 alone, we expect that roughly 32,000 Batswana or about 2% of the country's population will die of that disease. Even with significant changes in behavior, our model shows that around 540,000 Batswana, a number equivalent to about one-third of the country's current population, will die of HIV/AIDS during the two-decade period 2002–2021.

Main Finding (1): Little or No Population Growth

Here we present five population scenarios: (1) a continuation of the behavior exhibited in 1993–1997, modified to take into consideration current efforts to reduce the transmission of HIV from mothers to their children; (2) a situation in which government education efforts are successful in reducing the riskiness of people's behavior; (3) a government program of providing HIV medication to some of the population; (4) a government program of providing HIV medication to all those who can tolerate it; and (5) the elimination of all new HIV infections beginning January 1, 2002, through the use of a fully effective vaccine.

Figure 1 shows the population of Botswana in the two extreme scenarios, the continuation of current behavior and the deployment of a fully effective vaccine at the beginning of 2002. The population of Botswana is currently (2001) around 1.55 million people. Ten years from now, Botswana's population will be 1.53 million in the CONTINUATION scenario and 1.58 million in the VACCINE 2002 scenario. The difference is small because there is a long period

Box 1. The Botswana Demographic Model.

We have produced a detailed model of Botswana's population and run it from 1993 through 2021. It includes the population disaggregated by 100 single years of age, sex, three education levels, two types of sexual behavior (risky and not risky), four HIV statuses (HIV-negative; HIV-positive, asymptomatic and unmedicated; HIV-positive, asymptomatic and medicated; and AIDS), 15 single years since infection (for those HIV-positive, asymptomatic and unmedicated), and whether a young person has initiated sexual activity or not. The initial age-, sex-, and education-structure of the population is taken from the 1991 census, updated to 1993. Age-, sex-, and education-specific rates of HIV spread are derived from Sentinel Surveillance Survey data from 1993 and 1997, corrected, as best as possible, for biases resulting from the nonrepresentative nature of those data augmented by a few assumptions that can be changed by model users.

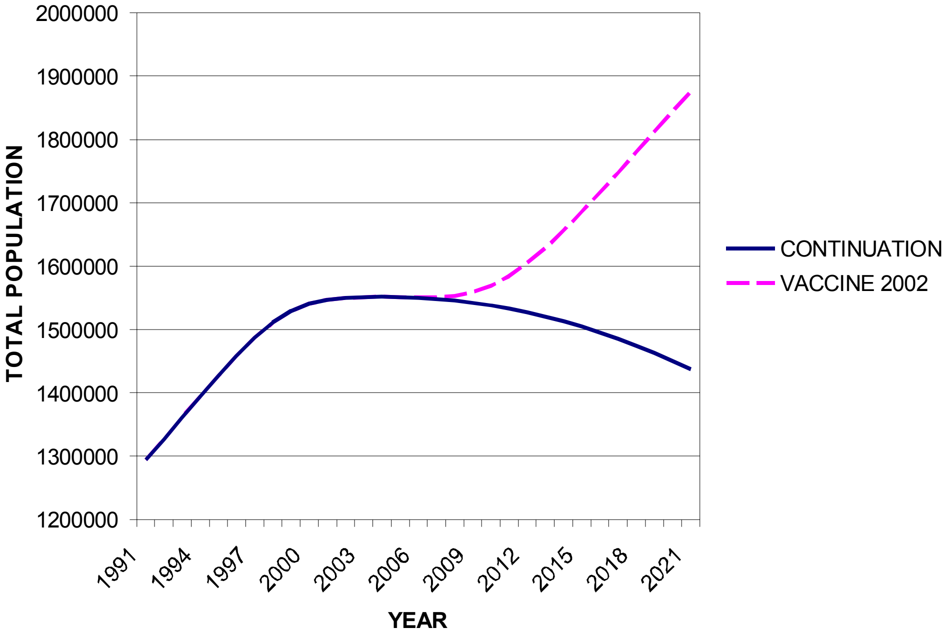

Figure 1. Population of Botswana under two extreme scenarios.

between infection with HIV and death. Most of the people who would become HIV-positive between 2002 and 2011 in the absence of a vaccine would survive to 2011 in any case. By 2021, the difference in population size is naturally much larger. In the CONTINUATION scenario, the population would fall to 1.44 million, while in the VACCINE 2002 scenario it would rise to 1.88 million. Both of these cases are unlikely, but they provide plausible upper and lower bounds on Botswana's 2021 population size.

Within the next two decades some behavioral changes will almost certainly occur. Government programs to produce these changes are already being put into place. Within the next two decades, as Batswana get wealthier and the price of HIV medication becomes cheaper, HIV medication will begin to be used. Figure 2 shows Botswana's future population size under a behavioral change scenario and two medication scenarios.

These scenarios are three among the vast number that can be created with the software that we have made available. They are meant to be illustrative. The BEHAVIORAL CHANGE scenario assumes that the riskiness of sexual behavior begins to decrease in 2001. Between 2001 and 2005, the HIV infection rate declines by 25% among those with primary schooling or less, 40% among those with secondary education, and 50% among those with tertiary education.

These behavioral changes have a cumulative effect. If fewer people engage in risky behavior, fewer people become infected with HIV and consequently there are fewer HIV-positive people around to infect others in the future. Thus, the long-run decline in HIV prevalence is greater than the percentages by which risky behavior is reduced.

In the PARTIAL MEDICATION scenario, medication use is initiated when an HIV-positive person first becomes symptomatic and ends when the medication is no longer helpful. We assume that the medication increases life expectancy by, on average, 10 years. There is no way of knowing the extent to which medication will increase the life expectancy, but the constant mutation of the HIV virus suggests that medications will become less effective over time. Medication use begins in 2002 with 10% of those with primary education or less who become symptomatic receiving medication, 15% of those with secondary education, and 20% of those with tertiary education. These differences could be due to differences in the ability to pay for the medication. The percentages receiving medication increase to 30%, 45%, and 60% for the low-, medium-, and high-education groups, respectively, by 2004 and stay at these levels through 2021. In the FULL MEDICATION scenario, 70% of the

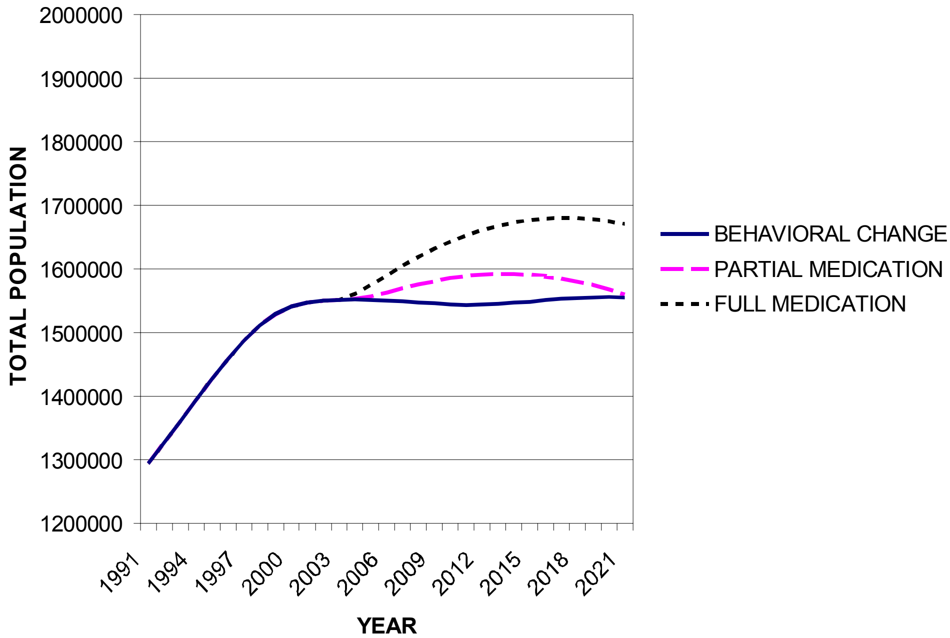

Figure 2. Population of Botswana under a behavioral change and two medication scenarios.

Box 2. HIV/AIDS forecasting.

An important equation used to forecast populations like Botswana's is the prevalence–incidence relationship. In our case, we used:

$$IR(age,education,year) = k(age,education) \cdot MAMPR(age,education,year)^{\beta}.$$

$IR(age,education,year)$ is the fraction of uninfected women in a particular age and education group in a given year who become infected during that year.

$k(age,education)$ is a set of age- and education-specific constants that are derived from two observations on HIV prevalence rates. In the case of Botswana, these observations are from 1993 and 1997.

$MAMPR(age,education,year)$is a moving-average modified prevalence rate. It takes into account the prevalence rates in a five-year window centered on the specified age and takes into account differences in risky sexual behavior of population groups and differences in the likelihood of spreading HIV depending on whether the infected person is on medication or not.

β is a parameter that is determined by the distribution of risky sexual behavior in the population.

people who become symptomatic, regardless of education, receive medication beginning in 2002. This scenario is called FULL MEDICATION because it is assumed that 30% of those who become symptomatic cannot tolerate the medication.

In the BEHAVIORAL CHANGE and the PARTIAL MEDICATION scenarios, Botswana's population hardly changes between 2001 and 2021. In the FULL MEDICATION scenario, Botswana's population increases from 1.55 million in 2001 to 1.67 million in 2021. There are, of course, many possible scenarios, including those with both behavioral change and medication. We have run quite a number of these and all plausible scenarios show little or no population growth in Botswana's near-term future.

Main Finding (2): Poor Quality HIV Data

The only data on the prevalence of HIV/AIDS that can be used for making population forecasts are the Sentinel Surveillance Survey data, which are derived from women seeking prenatal care. There are no data on men and therefore no way of modeling the transmission from women to men and vice versa. The Sentinel Surveillance Survey data come from small and nonrepresentative samples with no information on the women except their ages and the fact that they are pregnant. These data are geographically biased. For example, Francistown, with the highest HIV/AIDS prevalence rate in the country, provides more observations than Gaborone, which is many times its size. Pregnant women are not representative of all women of reproductive age. They are certainly younger, on average. Even holding age constant, pregnant women are not a representative group. If less-educated women of a given age are more likely to have children than more-educated women of that age, but have lower HIV prevalence rates than those women, reported rates are biased downward. The HIV prevalence rate of young women is certainly biased upward because young pregnant women are all sexually active and therefore not representative of a group where some of the women are not yet sexually active. A very significant bias is the one introduced by the relationship between HIV and fertility. HIV-positive women are less able to have a child than similar HIV-negative women. This imparts a significant downward bias to the Sentinel Surveillance Survey rates.

The Sentinel Surveillance Survey data are somewhat useful for describing aggregate trends, but they are very poor for analysis. The data can show no change when there is truly a large one and can even show changes when none are really occurring. There are easy ways to improve the data. Sample sizes can be increased. Geographical representativeness can be enhanced. Additional information can be gathered, so that we can better trace the effects of policies. More sophisticated tests can be used so that we can assess changes in the rate of spread sooner and more accurately. It is preferable to gather better data than to make policy mistakes, which could cause more deaths and suffering.

Main Finding (3):
Continued Urbanization

Figure 3 shows the urban population of Botswana for the CONTINUATION, BEHAVIORAL CHANGE, and PARTIAL MEDICATION scenarios. The urban population of Botswana is now (2001) around 785,000 people. In the CONTINUATION scenario, it peaks at 853,000 in 2016 before falling to 846,000 in 2021. Under both the BEHAVIORAL CHANGE and the PARTIAL MEDICATION scenarios, the urban population rises to around 930,000 in 2021. Gaborone currently has around 200,000 inhabitants. By 2021, we expect its population to increase by around 50%.

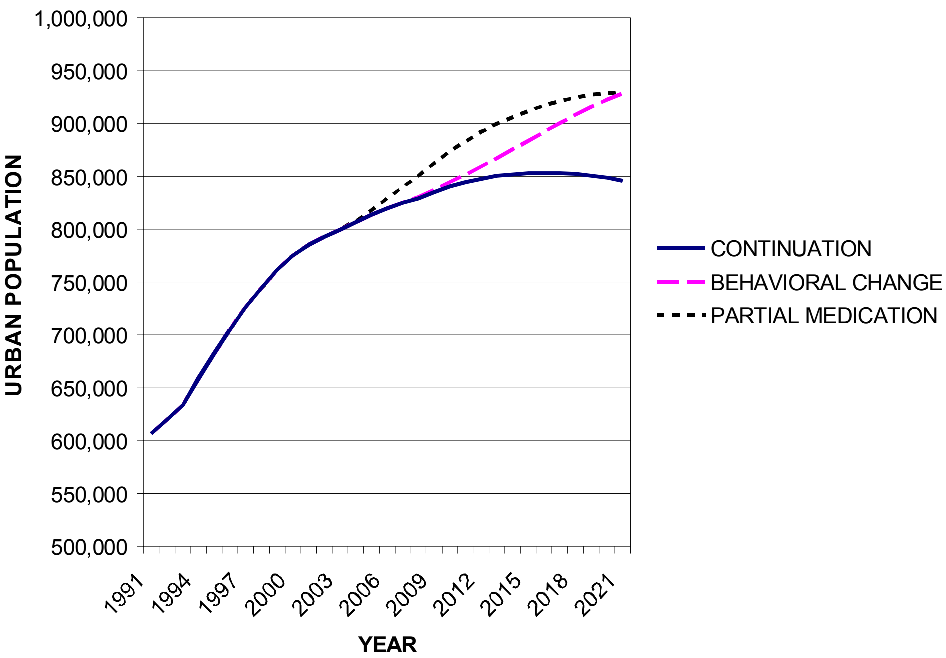

Figure 3. Urban population of Botswana under three scenarios.

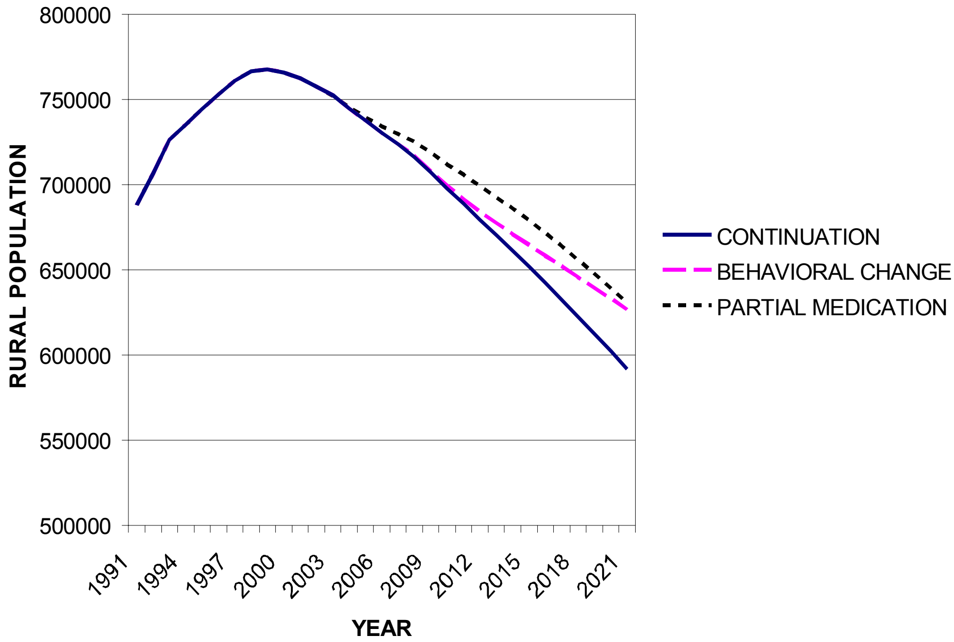

Figure 4. Rural population of Botswana under three scenarios.

An increasing urban population and a constant total population imply that the rural population of Botswana will decrease in size. Figure 4 shows the size of Botswana's rural population according to the same three scenarios. In all the cases the rural population declines. Currently, the rural population of Botswana consists of around 762 million people. In the CONTINUATION scenario, it would fall to 592 million in 2021. In the other two scenarios, the rural population falls to around 630 million, a decline of roughly 17%. When we discuss the labor force below, we will see that rural employment is likely to fall faster than the rural population, causing an increase in the ratio of the rural population below the age of 15 and above the age of 50 to the total rural population.

Main Finding (4): Rapid Education Transition

Because of past increases in enrollment rates, Botswana is in the midst of an era of rapid increase in the number of people with secondary and tertiary education. The HIV epidemic will not change this. Indeed, if more-educated people are more likely to change their behavior, or if they are more likely to receive medication for their infections, HIV could increase the size of the more-educated labor force even more. Figure 5 shows the labor force by two education groups, those with primary education or less and those with secondary education or more. These figures are based on the aggregate labor force participation rates observed in the 1991 census. Those activity rates will certainly change, but keeping them constant here is useful because the graph represents only the underlying education structure.

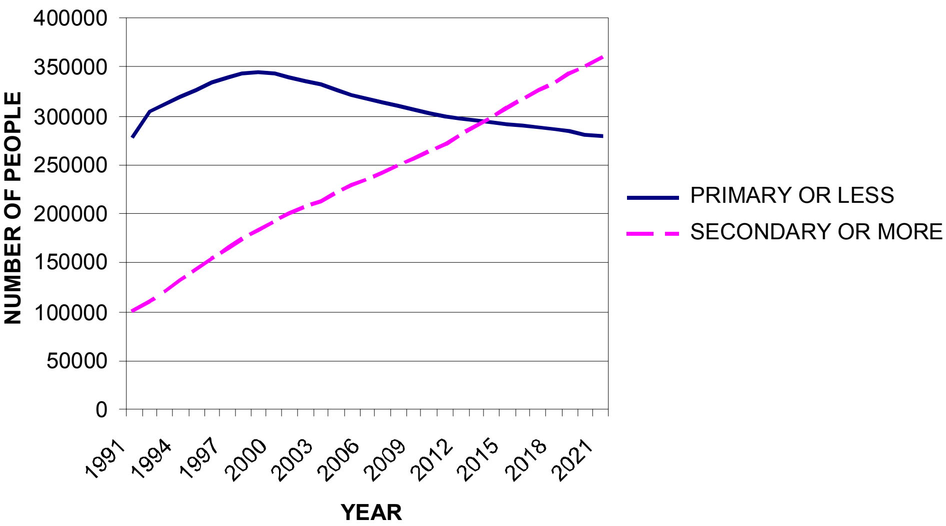

Figure 5. Botswana's labor force by level of education: BEHAVIORAL CHANGE scenario.

Using the 1991 economic activity rates, we calculate that the labor force currently consists of around 340,000 people with primary education or less and around 200,000 people with secondary education or more. At this time, the size of the less-educated portion of the labor force is shrinking and the size of the more-educated labor force is growing. In the BEHAVIORAL CHANGE scenario, the two paths cross in 2014. Assuming the 1991 rates of labor force participation (economic activity), the more-educated labor force will grow by around 80% from 2001 to 2021, while the less-educated labor force will shrink by around 18%. Finding jobs for the increasing number of more-educated workers will be one of the chief challenges facing policy-makers in Botswana in the next two decades, despite the high death rates due to HIV/AIDS.

Education and skills are not the same thing. There is some discussion in Botswana about a possible mismatch between the skills needed in the economy and the skills produced by the education system. Our research suggests that in the 1990s there were a significant number of people in the labor force with secondary education who held unskilled jobs.

Main Finding (5): Changing Age Structure

HIV/AIDS mainly kills people 30–39 years old. To see the effects of HIV/AIDS on the age structure, in Figure 6 we plot the numbers of people aged 20–29 and 40–49 in the BEHAVIORAL CHANGE scenario. In 2001, our model shows around 302,000 people aged 20–29 and around 112,000 people aged 40–49. By 2021, the number of people aged 20–29 is forecasted to grow to around 369,000, an increase of 22%, while the number of people aged 40–49 is expected to shrink to around 92,000, a decrease of 18%. The situation a few years earlier is even more unbalanced. Between 2001 and 2016, the population aged 20–29 is predicted to grow by 22%, while the population aged 40–49 is expected to shrink by 26%. The shrinkage of the population aged 40–49 represents a considerable loss of human capital.

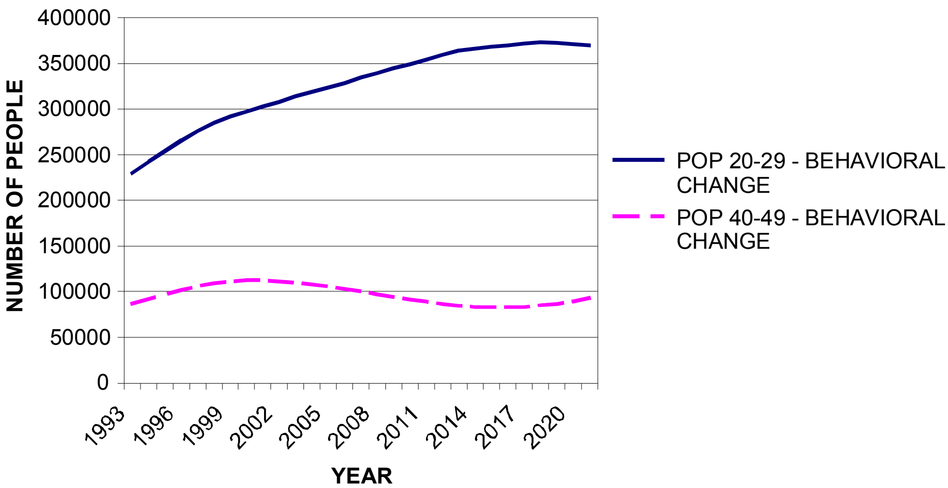

Figure 6. Number of people aged 20–29 and 40–49: BEHAVIORAL CHANGE scenario.

Main Finding (6): No Economic Catastrophe

Botswana has a small open economy that is driven by exports and constrained, in part, by a shortage of skilled workers. HIV could affect the economy through three main routes: (1) it could reduce exports, (2) it could diminish the number of skilled workers, and (3) it could reduce investment. The direct costs of HIV, such as additional health care costs, influence the economy mainly by decreasing investment. HIV also causes a reallocation of consumption expenditures from other goods and services to health care. This sort of reallocation has little economic effect (see Box 6). The situation in Botswana is different from that in many other African countries with high HIV prevalence. First, export growth is unlikely to be significantly affected. Botswana's main export is diamonds. Diamond production requires very few employees and produces a significant share of the country's output. Within the next two decades, diamond production certainly will not be limited by the size of

Box 3. The Botswana Economic Model.

Our results are based on a newly constructed three-sector general equilibrium model of the Botswana economy. The three sectors are non-agricultural exports, non-tradables, and agriculture. The non-agricultural export and non-tradable sectors are represented with nested constant elasticity of substitution production functions. Agricultural output is based on livestock herd dynamics and is affected by rainfall. Gross output in all sectors includes intersectoral flows and imports.

Available quantities of skilled and unskilled workers, as well as the number of people on HIV medication are derived from the Botswana Demographic Model (see Box 1). The skilled wage is assumed to clear the labor market, but unemployment of unskilled workers is allowed.

Policy dimensions of the model include a representation of the Government's adaptive macroeconomic management approach and the effect of expected changes in Botswana's foreign trade environment.

Botswana's labor force. Further, an increasing price of diamonds relative to import prices can drive economic growth without requiring additional labor. Since neither the output nor the price of Botswana's most important export will be affected by its high HIV death rate, Botswana's economy is less vulnerable to HIV-induced changes than many other African economies.

Box 4. Botswana's "tiger" economy.

Botswana has a small open economy whose growth is driven mainly by exports. The most important exports are those of the mining sector, particularly diamonds, copper, and nickel, and those of the agricultural sector, ranging from live animals to processed leather goods. Since its independence in 1955, Botswana has had one of the world's fastest rates of economic growth. Over the decade 1991–2000, real economic growth has averaged 5.5% per year.

Box 5. Sound macroeconomic management.

The Government of Botswana has a well-deserved reputation for sound macroeconomic management. In practice, this has meant that the Government has varied its spending so as to keep the rate of economic growth as high as possible while keeping inflation (relative to South Africa) in check. Given the structure of the economy, this has resulted in surpluses in the Government's budget (i.e., it spends less than it takes in). Because of its central importance to Botswana's economic success, we have incorporated a representation of the Government's adaptive macroeconomic management policies into our model.

Box 6. Gross Domestic Product is a poor measure of welfare.

Gross Domestic Product (GDP) does not capture the suffering caused by HIV/AIDS. From the perspective of national income accounting, food served at a wedding is identical to food served at a funeral. If a child is orphaned, the pain felt by that child does not decrease GDP, nor does the pain felt by the child's grandparents' having been cut off from the emotional and financial support of their own dead children. If the orphaned child goes to live with his or her elderly grandparents, and the grandparents are induced to work longer hours to care for him or her, GDP actually increases.

High HIV/AIDS death rates will certainly reduce the number of skilled workers, but as we saw in Main Finding (4), the number of people in the labor force with a secondary education or more is expected to increase by around 80% between 2001 and 2021 anyway. It will be a major challenge for the

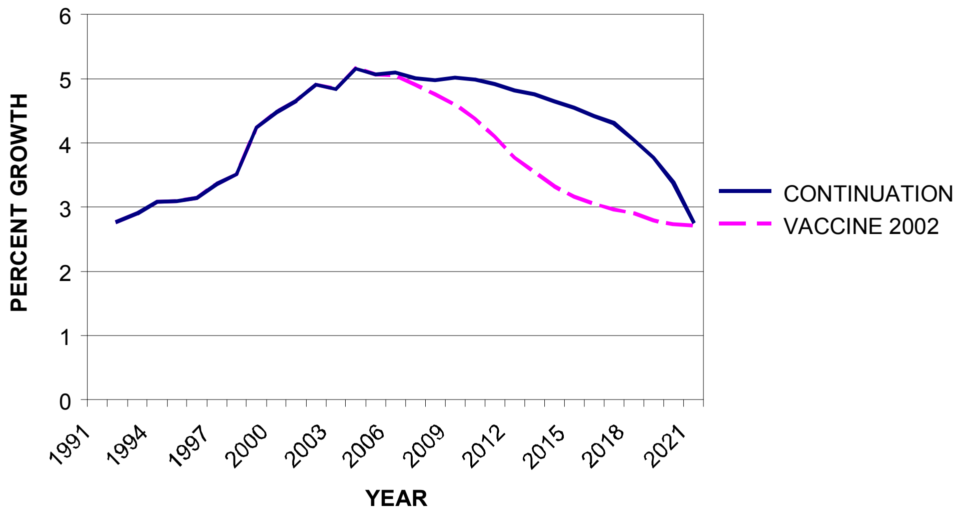

Figure 7. Percent per capita real GDP growth in the two extreme scenarios.

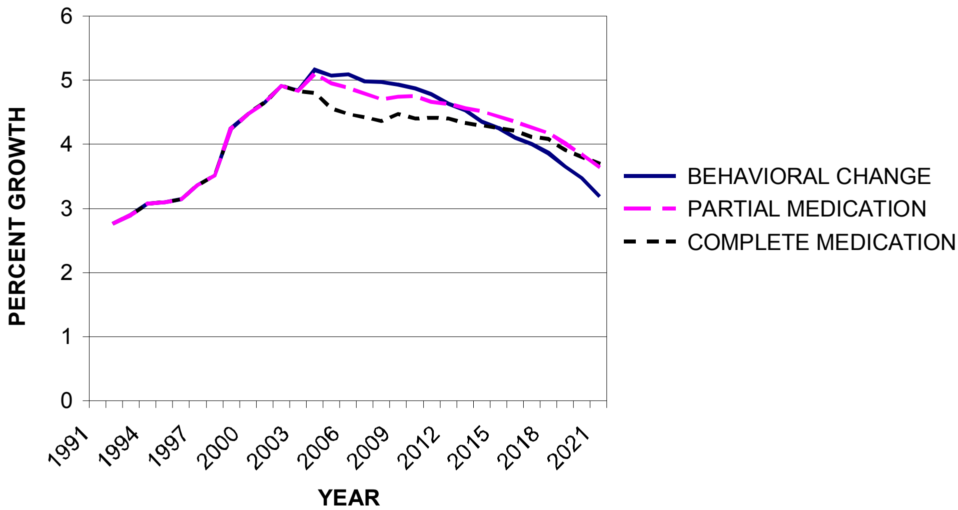

Figure 8. Percent per capita real GDP growth in three scenarios.

economy of Botswana to absorb this large increase in skilled labor. Thus HIV/AIDS will not cause a shortage of skilled workers. HIV/AIDS could reduce economic output by curtailing investment. There are a number of reasons to believe that this effect is not likely to be large. Some people argue that HIV/AIDS reduces investment because it diminishes savings. In the Botswanan economy, savings generally exceeds investment. Therefore, a reduction in savings may not translate immediately into a decline in investment. In Botswana, investment is driven more by profitability than by savings.

The rate of real per capita output growth is shown in Figure 7 for the CONTINUATION and VACCINE 2002 scenarios, and in Figure 8 for the other three scenarios. We use only one economic scenario here in order to keep our discussion clear. It matches Botswana's economic performance in that the average rate of economic growth over the period 1991–2001 is the same as the observed rate, and growth is faster at the end of the decade than at the beginning. Nevertheless, the economic scenario is designed to reproduce the major trends in the Botswanan economy, not its exact year-to-year changes.

In all five population scenarios, a growth rate of per capita output of around 5% per year is maintained throughout the current decade. In the following decade, the economic growth rate falls. Under the extreme scenarios, the rate declines to slightly under 3% per year by 2021. In the other three, the rate of growth falls only to between 3% and 4% per year. The main point is clear: HIV/AIDS will not cause an economic catastrophe in Botswana.

Main Finding (7): Trade Changes Will Be Helpful

In Figure 9, we consider how expected changes in Botswana's trading regime interact with the changes caused by HIV/AIDS. In the context of the BEHAVIORAL CHANGE scenario, we see that decreases in tariff rates result in faster economic growth. In our baseline economic scenario, tariffs decline by around 90% from 2002 through 2021. Since the tariff changes are to be introduced only slowly, the greatest effect is seen only after 2015. Figure 10 shows the effects of the tariff reductions on government revenue and on the surplus. In 2021, the surplus would be 3.14 billion 1991/1992 pula with constant tariff rates and only 0.5 billion pula with the expected fall in tariff revenue. Throughout most of the two-decade period to 2021, the surplus is a substantial fraction of government revenues. In 2011, for example, the surplus is around 15% of revenue.

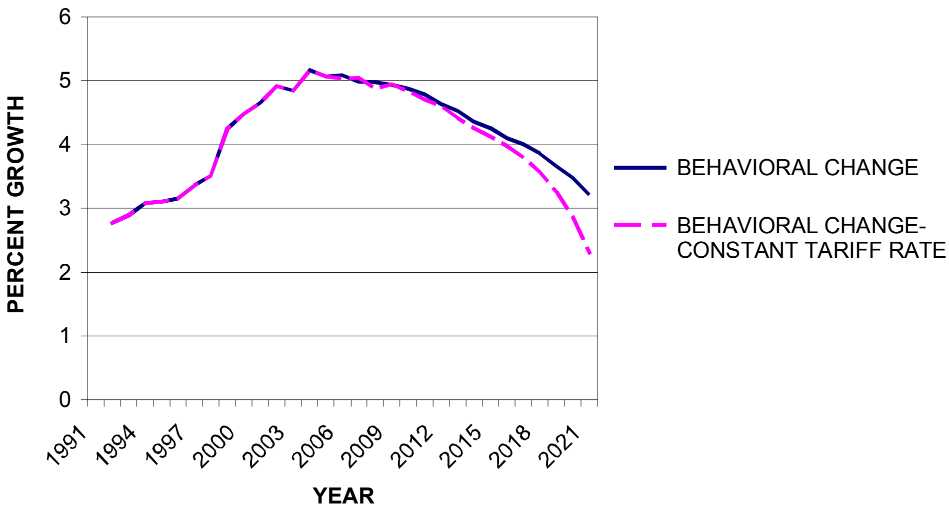

Figure 9. The effect of a tariff reduction on per capita GDP growth: BEHAVIORAL CHANGE scenario.

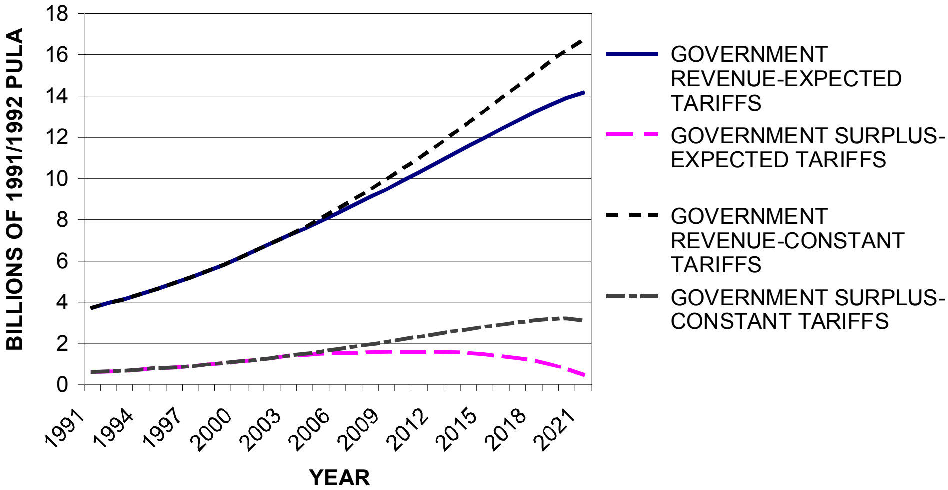

Figure 10. Government revenue and surplus with expected and constant tariff rates: BEHAVIORAL CHANGE scenario.

Box 7. The challenge of changing foreign trade regimes.

In addition to HIV/AIDS, Botswana will have to cope with a rapidly changing trade environment as a result of the Cotonou Agreement with the European Union, the European Union–South Africa Free Trade Association, the U.S. African Growth and Opportunity Act, and World Trade Organization rules. The most direct effects of changes in the trade environment are to reduce tariff revenues going to the Government of Botswana and to reduce import prices faced by domestic producers and consumers. These effects are incorporated into our model. See Box 3.

The effects on output growth are more difficult to predict. In the short run, Botswana will face stiffer competition for its regional exports. In the longer run, a larger free-trade area could stimulate exports.

Main Finding (8): HIV Medication Affordable

The pharmaceutical companies GlaxoSmithKlein, Bristol-Meyers Squibb, and Boerhinger Ingelheim have committed themselves to selling HIV medication to governments of developing countries at a price currently around US$1,100 per person-year. An Indian pharmaceutical company, Cipla Ltd., has offered the same medication for US$600 per person-year of coverage. These new lower prices have dramatically increased the ability of governments to finance the provision of medication. Figure 11 shows the cost of medication as a percentage of the Government of Botswana's revenue and of its surplus for the FULL

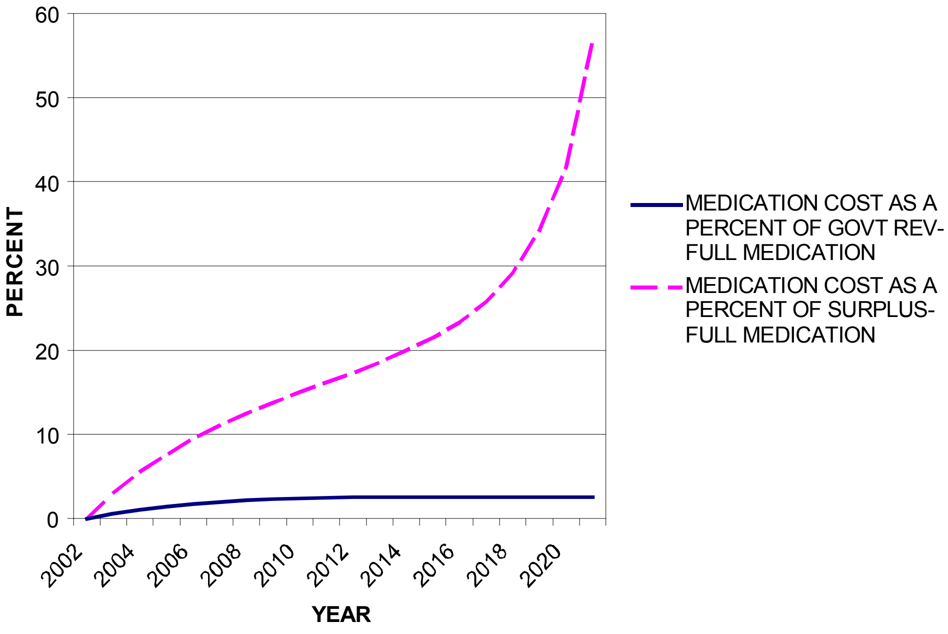

Figure 11. Medication as a percentage of government revenue and surplus under the FULL MEDICATION scenario, US$1,100 per person-year of coverage.

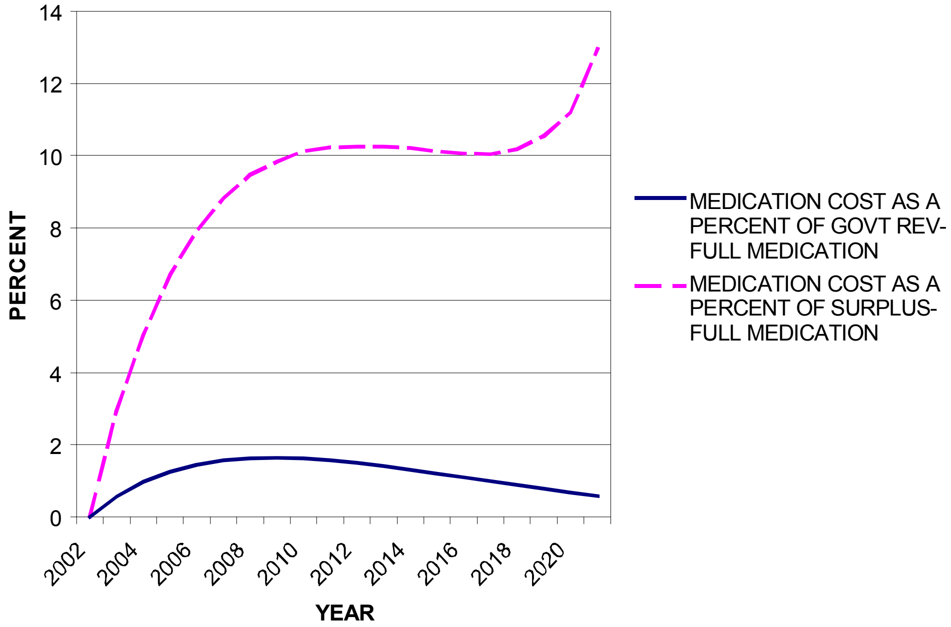

Figure 12. Medication cost as a percentage of government revenue and surplus under the FULL MEDICATION scenario, US$1,100 per person-year of coverage year in 2001 falling to US$250 by 2021.

MEDICATION scenario, holding the US$1,100 price constant. The FULL MEDICATION program never costs more that 2.6% of the Government's revenue. For most of the period, the program costs less than 30% of the Government's surplus. If instead we were to use the US$600 figure, the cost would never exceed 1.4% of the Government's revenue and would, for most years, cost less than 16% of the surplus. Figure 12 is the same as Figure 11, except that the cost of medication is assumed to fall gradually from US$1,100 per person-year in 2001 to US$250 per person-year in 2021. In this case, in 2021 the medication would cost less than sixth-tenths of one percent of revenue and less than 13% of the surplus.

The FULL MEDICATION scenario can be financed out of the expected future government surpluses without a reduction in any other expenditures. Providing medication has the important consequence that more people are kept alive and a great deal of misery is alleviated. A rather cold-hearted question is whether using the surplus in this way would have negative economic consequences. After all, the surplus exists in the first place because of the danger that its use would generate excessive inflation. As it turns out, spending the surplus to keep people alive works to reduce inflation. Thus, financing the FULL MEDICATION scenario out of the surplus is a win–win situation. Suffering is reduced and the Government's successful macroeconomic management strategy is enhanced.

The most important disadvantage of a FULL MEDICATION strategy is that it would reduce the incentive to adopt less risky behavior. We saw in Figure 2 that the population of Botswana under the FULL MEDICATION scenario was only marginally higher than under the BEHAVIORAL CHANGE scenario. The second disadvantage is that the cost of medication is only one component of an effective medical intervention program. At present, close physician monitoring is required for the medication to be used effectively. Botswana's medical infrastructure may not yet be able to handle the vastly increased demands placed upon it by the FULL MEDICATION scenario. The third disadvantage is that use of the surplus to finance HIV medication limits the use that policy-makers can make of the surplus as a tool for macroeconomic stabilization. Nevertheless, the Government of Botswana can now afford to provide HIV medication to all those who can benefit from it. The question of whether or not to do so is no longer an economic one, but a political one. If the Government of Botswana pursues such a program, aiding Botswana's medical infrastructure should be a high priority for external donor organizations.

Main Finding (9): Unemployment Decreases

Botswana has a history of high unemployment and underemployment. This will change in the next two decades. Unemployment will diminish progressively and unskilled laborers will become a much needed resource. Our model assumes full employment for people with a secondary education or higher, but allows unemployment of people with primary education or lower. Figure 13 shows the employment of unskilled non-agricultural labor and the supply of unskilled labor to all sectors, using 1991 age- and sex-specific labor force participation rates. The two curves cross in 2006. In other words, in that year there would be full employment of all unskilled workers in the non-agricultural sectors and no unskilled workers left in agriculture. This is, of course, impossible. Participation rates will increase. Nevertheless, by 2021 unskilled non-agricultural employment is around 50% higher than the number of unskilled people who

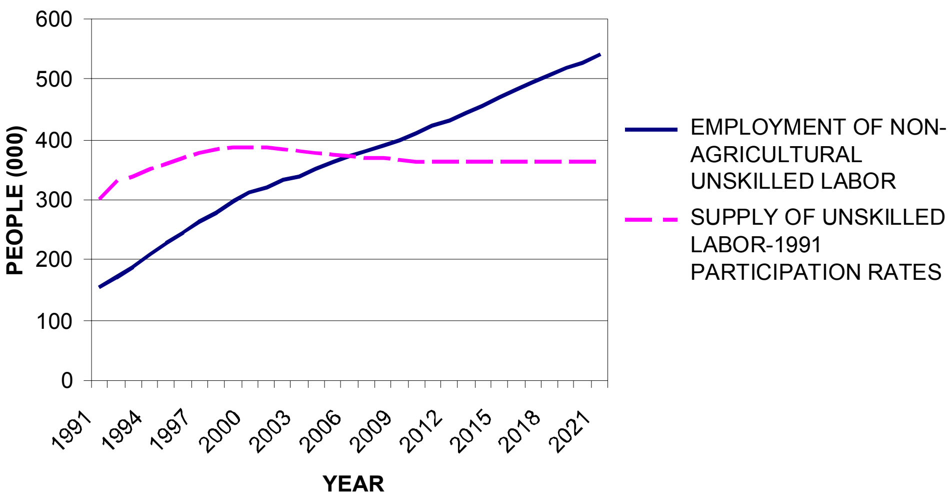

Figure 13. Employment of unskilled non-agricultural labor and supply assuming 1991 participation rates: BEHAVIORAL CHANGE scenario.

would work in all sectors if employment patterns stayed as they were in 1991. Even with substantial increases in female and male participation rates, this implies that unskilled labor in agriculture will diminish significantly.

In the past, Botswana has taken in foreign skilled workers, in part to raise the rate of economic growth and provide jobs for its numerous unemployed. In the near future, the situation will be different. The stock of domestic skilled workers will increase rapidly. More foreign skilled workers could still be brought in to increase the rate of economic growth, but this would produce upward pressure on the wage rate of unskilled workers and perhaps induce the in-migration of foreign unskilled workers.

The agricultural sector has been Botswana's main employer. This is changing rapidly and will continue to change. With more and more skilled employees and fewer unemployed and underemployed unskilled workers, an important challenge faced by Botswana will be how to use its increasingly relatively scarce unskilled labor force most efficiently.

Main Finding (10): Water Stress Increases

To assess water stress, we divided Botswana into three Socio-Ecological Regions (SERs) (see Figure 14) based on the existing demographic and hydrologic characteristics of the country. SER1 encompasses the Ngamiland district. This district covers an area of roughly 90,000 km^2, or about 16% of the total land area of Botswana. The main feature of Ngamiland is the Okavango Delta. The Limpopo sub-basins and the eastern Botswanan border define SER2, which covers almost the same area as SER1. SER3 encompasses the Kalahari Desert and the northeastern portion of Botswana. It covers about 394,000 km^2, or about 68% of the area of Botswana.

Figures 15, 16, and 17 show the supply/demand ratio (see Box 8) over time for the SERs for each of the 30 generated climates for the VACCINE 2002

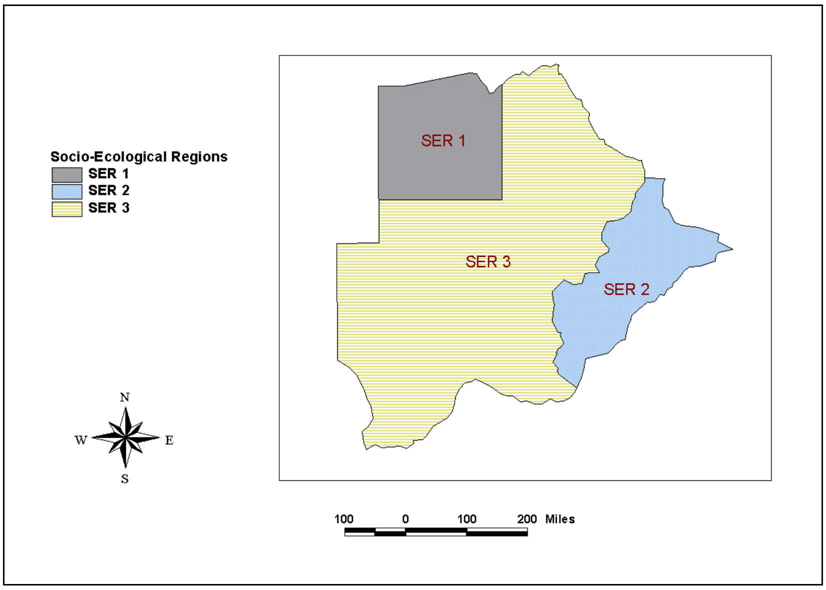

Figure 14. Socio-Ecological Regions of Botswana.

Box 8. Water stress indicator.

The supply/demand ratio serves as a proxy for average water-related stress on both ecosystems and socioeconomic systems. Average annual supplies include groundwater recharge and total usable surface supply. Inflows include both domestic resources and inflows from other countries. The demands stem from various sectors: energy, institutions, industry, mining, agriculture and livestock.

Four classes are defined: no stress, low stress, stress, and high stress. Several literature sources indicate that at ratios of less than 5, water stress can become a limiting factor on economic development.

	No stress	Low stress	Stress	High stress
Supply/demand ratio	greater than 10	5 to 10	2.5 to 5	less than 2.5

scenario. These have been generated using the Botswana SER Water Resources Model (see Box 9). In each of the SERs there is a decline in the supply/demand ratio over time, indicating an increase in level of water stress as we approach 2020. This is mainly the result of the increase in water demand caused by population growth, urbanization, and industrialization.

The water-rich northern region (SER1) is predicted to be highly stressed throughout the analysis. This stress level may seem surprising; however, most

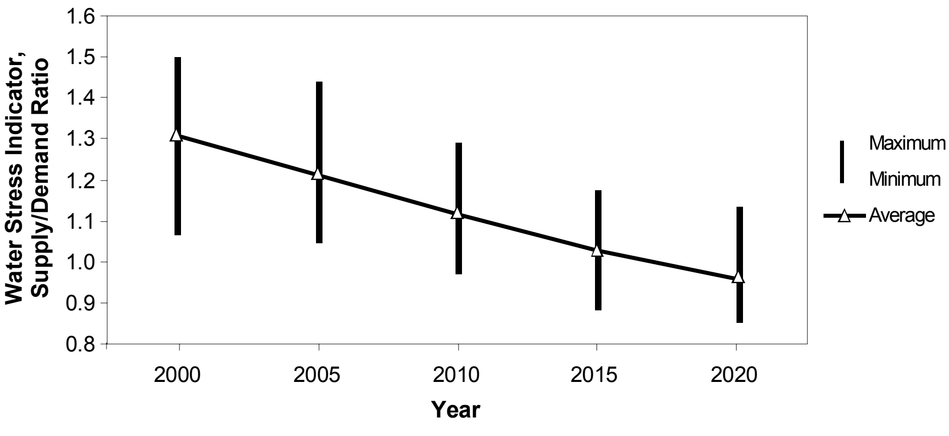

Figure 15. Water stress in SER1: VACCINE 2002 scenario. Maximum, minimum, and average of 30 climate runs, no global climate change. *Note*: Because of extreme stress, stress thresholds do not appear.

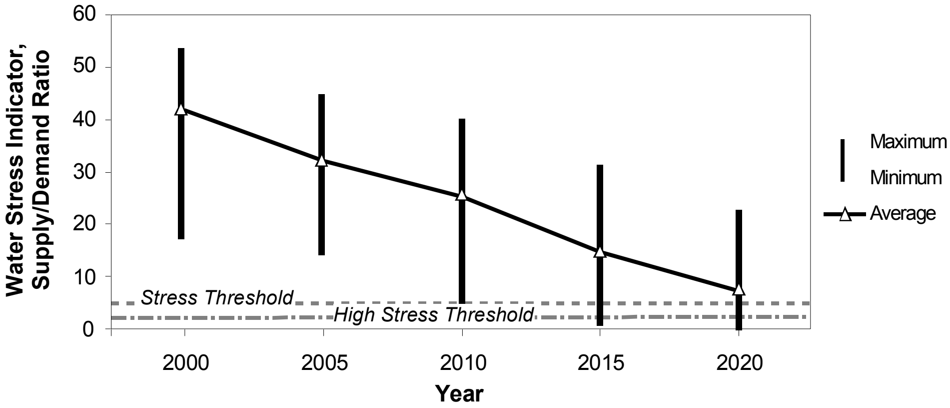

Figure 16. Water stress in SER2: VACCINE 2002 scenario. Maximum, minimum, and average of 30 climate runs, no global climate change.

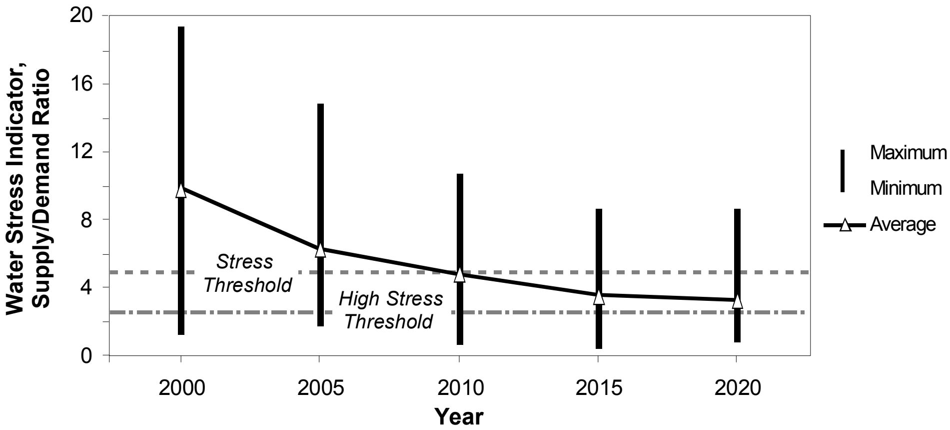

Figure 17. Water stress in SER3: VACCINE 2002 scenario. Maximum, minimum, and average of 30 climate runs, no global climate change.

of the water that flows into the Okavango Delta is consumed by evaporation and held in the swamps. The outflow in Maun's main river (the Thamalkane) has been dropping rapidly over the past 30 years. In Maun demand exceeds sustainable supply by about 2,000 cubic meters a day and the water is too salty for most people's tastes. The high water stress is due, in part, to the lack of water storage infrastructure. Any effort to take water from the delta will make matters even worse.

Box 9. The Botswana SER Water Resources Model.

We have constructed a detailed model of Botswana's water supply and demand. It is designed to provide forecasts of future regional water supply and demand for Botswana in order to determine the sustainability of the water supply under various forecasts of economic, population, and climate changes. The model produces probabilistic forecasts of available water supplies depending on the quantity and timing of rainfall. Five major hydrologic basins were delimited for analysis: Upper Zambezi, Okavango Delta, Orange River, Southern Interior, and the Limpopo. These basins were aggregated into macrobasins from sub-basin maps. The model uses a monthly time step to incorporate the seasonality of the basin hydrology. The modeled runoff of each basin is distributed to each SER depending on the water resources infrastructure. The initial water demand data were taken from 1989 Water Utilities Corporation data and updated to 1993. Data on river basin flows, precipitation, groundwater, and infrastructure were taken primarily from the 1991 Botswana National Water Master Plan, the Department of Water Affairs, ALCOM Fisheries, the Links Dataset, and the National Center for Atmospheric Research (USA). Soil moisture data were derived from the Dunne dataset. The model assumes that water infrastructure currently being built will be completed.

Box 10. Stochastic modeling of water resources systems.

When modeling water storage systems, the sequence of floods and droughts is key to system performance. Since the exact values and sequence of future monthly rainfall quantities are uncertain, an ensemble of monthly climate variables was generated using stochastic generation techniques. For each scenario and watershed basin, 30 different climates for 20 years were generated and run through the model, yielding probabilistic future water supplies. These climate series were produced by the Stochastic Analysis and Modeling System (SAMS) model and preserve the patterns of rainfall over time and across regions.

SER2 has the highest water use of the three regions, taking almost 80% of Botswana's annual water consumption. However, this region also contains all of Botswana's major storage reservoirs. In our projections, water stress increases rapidly. New groundwater sources are expected to relieve some of the burden of this growth in demand, but their use might be unsustainable. It is likely that conservation measures as well as new infrastructure will have to be implemented to manage water stress.

The central and western portions of Botswana (SER3) will also experience an increase in water stress. This region is sparsely populated, with little water infrastructure and a high reliance on groundwater sources. Precipitation is evaporated or transpired from the surface quickly.

Main Finding (11): Phase II of North South Carrier Unnecessary

The 1991 Botswana National Water Master Plan indicated that by the year 1998 the Gaborone area would require additional supply sources and that those would be drawn most economically from the northeastern portion of the country. These concerns led to the construction of the North South Carrier (NSC). With its completion in 2000, the NSC allows the transfer of water via a 360-km pipeline running from the Letsibogo Dam in the north to the Mmamashia treatment works in the south. Figure 18 shows SER2 and pertinent infrastructure and demand nodes included in the analysis.

Figure 19 shows the increase in the water stress level over time for the CONTINUATION scenario. Notice that the water stress in Gaborone is lower in 2005 than in 2000; this reduction is due to the completion of Phase 1 of the North South Carrier. Gaborone's water supply should be sufficient for the next

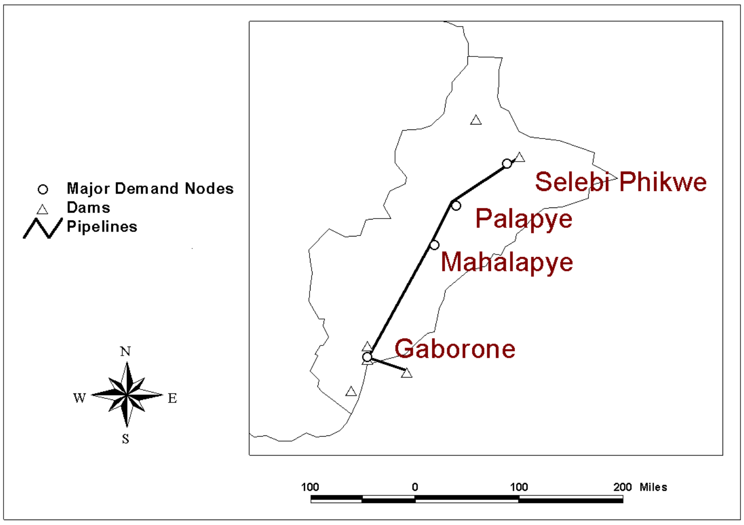

Figure 18. Gaborone surface water supply infrastructure.

Box 11. Modeling Gaborone's water supply.

Gaborone's water supply was modeled using information on the existing water resources infrastructure. Currently the city receives its water from four major dams – Bokaa, Gaborone, Molatedi, and Letsibogo – and from groundwater. Four main demand nodes were included in the model: greater Gaborone, Palapye, Mahalapye, and Selebi-Phikwe. It was necessary to incorporate these additional centers as they share water supplies with Gaborone through the North South Carrier. Water transfers to Gaborone are governed by certain rules. The amount of water transferred to the Gaborone Dam from the Molatedi Dam in South Africa is restricted by an agreement between the two countries and depends upon the volume of water in the Molatedi Dam. Water is transferred from Bokaa to the Gaborone Dam to take advantage of Gaborone's better storage-to-evaporation characteristics (less evaporation for the amount of water). Transfer of water from the Letsibogo Dam via the North South Carrier is restricted by pipe diameter to 112.5 million liters per day. In this modeling exercise, Gaborone's water needs were given priority over the other demand centers serviced by the North South Carrier (Mahalapye and Palapye).

20 years, barring a prolonged drought. However, by 2020, Gaborone will experience water stress almost 25% of the time, and has a probability of being highly water stressed over 20% of the time.

One approach to reducing water stress is conservation. In Figure 20, we show the results of a simulation where domestic water use per capita is held at

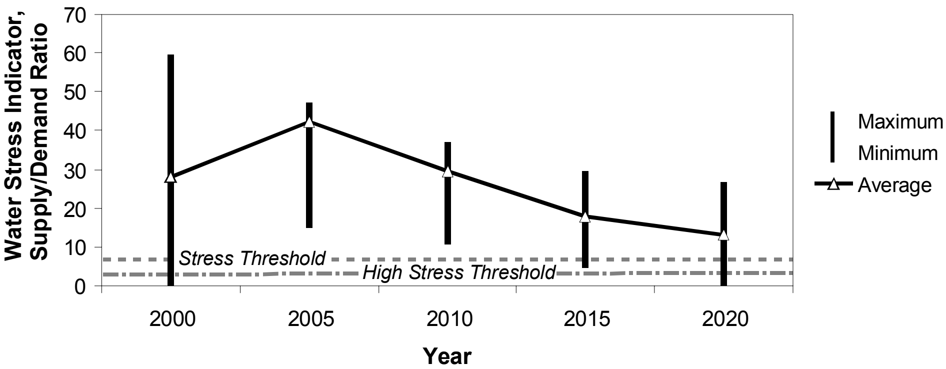

Figure 19. Water stress in Gaborone: CONTINUATION scenario. Maximum, minimum, and average of 30 climate runs, no global climate change.

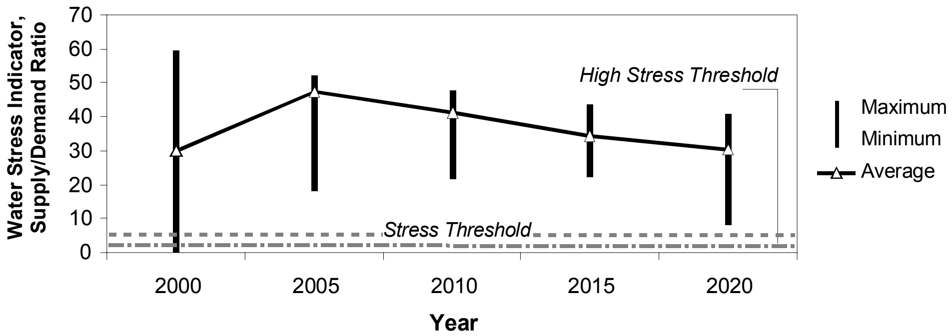

Figure 20. Water stress in Gaborone: CONTINUATION scenario and a water conservation scenario. Maximum, minimum, and average of 30 climate runs, no global climate change.

its 2001 level and non-domestic water use rates decrease gradually to 80% of their 2001 levels by 2020. With these decreases in water consumption, Gaborone's water will be virtually unstressed by the year 2020. If effective demand-side management policies are initiated, it is probable that Phase II of the North South Carrier, which would bring more water to Gaborone from the north, will not be necessary to sustain the urbanization and development of Gaborone.

Main Finding (12): Global Climate Change Uncertainties

Global Circulation Models (GCMs) of the Earth's climate show inconsistent changes for Botswana over the next two decades. We took predicted monthly rainfall and temperatures from three well-known GCMs and ran them through the Botswana SER Water Resources Model. We compared the outcomes to the previously computed figures, assuming no climate change. The implications of global climate change ranged from a very slight decrease in water stress to a very significant increase in water stress.

Given the uncertainties of future temperatures and rainfall, it would be reasonable to take precautions and plan for drier conditions. It takes a long time to build pipelines and dams and to implement conservation measures – about the same amount of time that it takes, in some GCMs, for significant additional water stress to occur.

Main Finding (13): Groundwater Difficulties

New groundwater sources are expected to relieve some of the burden of increasing demands. However, caution must be used when considering exploitation of additional groundwater sources to supplement future water supply. There is great uncertainty as to the amount of groundwater recharge in Botswana. Additional use may be unsustainable. According to the Botswana National Water Master Plan, groundwater production is expected to nearly double by the year 2020. Even assuming that this level of production is sustainable, our analysis shows that Botswana will still experience water stress in the future. Figure 21 shows the water stress results for the VACCINE 2002 scenario, with the increased groundwater pumping in SER2 by 2020. While new groundwater sources are being explored, many existing sources are being overused, or have already been contaminated.

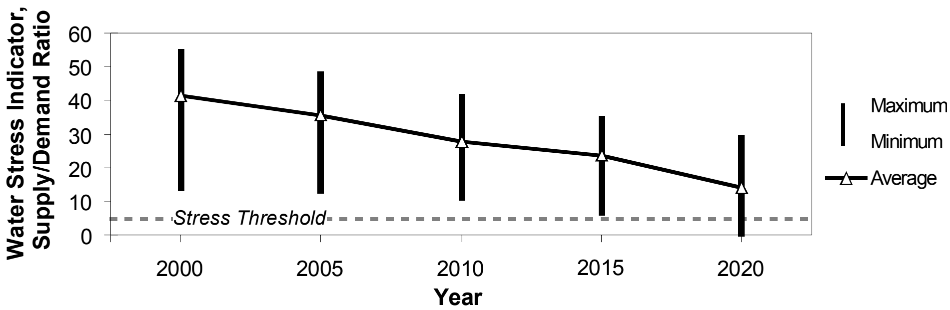

Figure 21. Water stress in SER2, VACCINE 2002 scenario with new groundwater sources. Maximum, minimum and average of 30 climate runs, no global climate change.