AIDS and Africa – when will the epidemic level off

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Introduction

The principle of population dynamics declares that it is environmental factors such as changes in physical conditions, food supplies and the occurrence of natural enemies that determine the population size of any species in existence in a given area at a given point in time. These factors vary all the time, as the organic and inorganic environment is in a constant state of change. Every change that takes place in a species' living conditions is reflected in its numbers. Examined over a period of time, this takes the form of a constant search for a state of equilibrium, which in an undisturbed situation would result in a fluctuation around a certain average figure.

In the course of its endeavours to create a favourable environment for itself, human society has systematically attempted to prevent the spread of epidemics (McMichael 1993). Even so, the causes of such disasters were still unknown in the early nineteenth century, and it may be said that they were thus the last factors effectively limiting human population growth. Many of the advanced cultures of prehistoric times were obliged to carry on a bitter struggle for existence against the repeated threats posed by epidemics. Later the serious outbreaks of the plague in Europe and elsewhere can be identified in the population curves in form of dips in total population figures (Cliff & Haggett 1988; Epstein 1995; Löytönen 1995).

At the micro level, an imbalance comparable to the laws of population dynamics prevails between humankind and the microorganisms that bring about diseases. Viruses, bacteria and other microbes are constantly altering their genetic make-up in search of new properties that will give them a hold over the human body, which has often become able to resist their attacks by virtue of its immune defence mechanism. One should also bear in mind that the human body for healthy life needs some microbes. And in some cases, the infection by a potentially harmful microbe does not always lead to a clinical disease. *Tuberculosis bacillus* – estimated to be carried by one third of the global human population – develops into a clinical disease in only 10% of the infected population during their lifetime provided no cofactors are present.

The discovery in the second half of nineteenth century of the microorganisms responsible for the diseases was a scientific breakthrough that revolutionised our concepts of many human illnesses. It meant that the cause of infectious diseases could be pinpointed and progress could be made in their treatment, in the sense that for the first time in the history of humankind it was known what agent was responsible for the plague, for example. Since that time, improved hygiene, antibiotics, inoculations and many other basic techniques of modern medicine have proved effective in combating infections, perhaps the best example of which lies in the total elimination of smallpox as a result of the international vaccination campaign (Cliff et al. 1981; Cliff et al. 1986; Cliff & Haggett 1989).

The advances in the medical sciences together with increasing economic resources and better education resulted in improved quality of life and increased life expectancy – but mostly for people living in the industrial world. Healthy life and long life expectancy are so dependent on economic and intellectual resources and the organising of the society – health care provision, access to education, and other similar elements – that many countries in the developing world have little to offer to their citizens. In this respect, Africa is probably the clearest example of how complex health-related problems can threaten the existence of entire nations (Barnett & Blaikie 1992; Bond et al. 1997).

The diffusion of the infection with the Human Immunodeficiency Virus (HIV) throughout the world constitutes a formidable example of a process of what has been said above. In just over two decades, it has managed to spread everywhere reminding people in both rich and poor countries that the balance between harmful microbes and the humankind during the second half of the twentieth century was nothing but one transient moment in the continuous search for a balance. While the growth curves of AIDS cases in most industrial countries are currently beginning to level off (Fig. 1), the curves in many developing countries such as India are growing rapidly with no signs of levelling off (Chin & Mann 1988; Smallman-Raynor et al. 1992; Pan American... 1997; The status... 2000; European centre... 2002; AIDS epidemic… 2003).

Recognising that predominant modes of transmission vary by world's regions and that there is a relationship between health and development, an understanding of the diffusion process, of the future growth, and of the predominant variables involved in it at a particular place are essential for disease intervention and for planning of the provision of health care. Such demands are accomplished by modelling and forecasting the spread of any epidemic. In this paper, I will first briefly discuss the HIV pandemic and different approaches to geographical modelling and forecasting. At the end of my paper, I will focus on AIDS in Africa and what will be the final level of prevalence once the growth curves begin to level off.

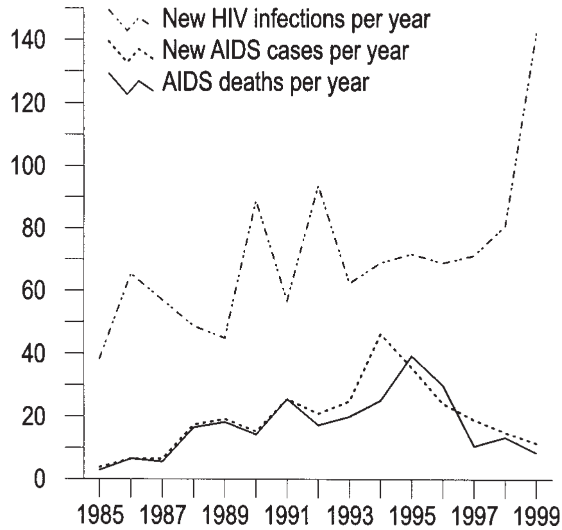

Fig. 1. HIV carriers, AIDS cases and AIDS deaths in Finland since the beginning of the epidemic. After the initial phase, the number of new HIV carriers oscillated around a broad mean value until the late 1990s. Then, largely due to the rapid increase of iv drug users, the number of new HIV carriers jumped to a new, much higher level. This is a typical example of the interaction between the population size and the factors controlling it in a given area.

African origin – but human sponsored

As far as is known at present, the HI virus originates from East Africa where it, or some early prototype of it, first infected humans from three species of monkey found in the area. It was very probably endemic throughout the nineteenth century in the territory inhabited by these monkeys. No epidemic ensued, however, because African society was for a long time sufficiently static, with people's movements restricted to their own village or tribal community (Shannon & Pyle 1989; Shannon et al. 1991; Smallman-Raynor & Cliff 1990, 1991; Gao et al. 1999).

The situation altered after the Second World War, as the structural changes in the society and the associated urbanisation, trade and industrialisation led to greater mobility in Africa. It was at this stage that the HI virus began to spread to wider areas and that the disease assumed the proportions of an epidemic in Africa (Barnett & Blaikie 1992). It is possible that individual travellers visiting the continent in the 1950s may have become infected, but these cases will not have attracted any particular attention from the health authorities, and any deaths that occurred must have simply remained aetiologically unresolved. Thus, the HIV pandemic started and developed unnoticed.

The situation finally came to light in the early 1980s, when the number of cases escalated and the disease came to the attention of the health authorities in the USA (Gould 1993; Gould & Wallace 1994).

From the modelling point of view, it is rather essential to ask how it is possible that the HI virus – slow to migrate and easy to avoid with little knowledge of the few of modes transmission – managed to spread beyond Africa to cause a pandemic extending over the entire inhabited world. The answer to this question is geographically a very interesting one – and challenging. The biological regularities that maintain a state of equilibrium between a human being and the microbes that threaten him or her have developed to their present state over a period of 100–200 million years, and may be said to have safeguarded the existence and growth of the human populations fairly well under the conditions in which the human species evolved. Populations were small, and the density of settlement was not very great, in addition to which the world was for a long time inhabited by isolated human groups with no contact with one another (e.g., Gould 1989).

During the modern times, however, conditions for the occurrence and spread of epidemics have altered drastically (Flahault & Valleron 1992; Haggett 1994. There has been what can only be described as a population explosion; people have moved to live in agglomerations of tens of millions residents, mobility has increased, and the speed of travel has become such that any point on the globe can be reached in a few hours. It is highly probable that the HIV pandemic would never have come to anything if human society itself had not altered its environment and ways of living as we have seen over the past few centuries.

One pandemic – many epidemics

From the geographical point of view, the HIV epidemics in the various continents – and in various countries as well – appear to be developing in different ways (Arbona & Löytönen 1997; Lamptey 2002). During the first decade of the HIV epidemic, it was common to characterise the pandemic in terms of four global patterns of HIV transmission. The rapid changes in the epidemiological patterns e.g., in India and Vietnam have shown that the earlier classification of four patterns no longer holds true. The more recent view of the pandemic emphasises the multiple patterns of HIV epidemic even in neighbouring countries (Stoneburner et al. 1994, 1996; Mertens & Low-Beer 1996).. Because HIV infection in many countries has occurred disproportionately in certain high-risk groups (European centre... 2002; The status... 2000) dramatic differences can be found even within a country or region. Significant differences in prevalence can also be observed between rural and urban areas (Lam & Liu 1994). In addition to these factors, social strata within a population have associated epidemiological characteristics that may facilitate or hinder transmission of HIV.

Perhaps the most striking difference in the number of AIDS cases is between the industrial countries and the developing world (Fig. 2). At the beginning of the new millennium, the UNAIDS and WHO estimated that 42 million adults and children are living either with HIV or AIDS. More than 20 million have already died of the disease. The vast majority – ca. 95% – of the people living with HIV or AIDS live in the developing countries. This proportion is expected to continue to increase as poverty, poor health systems, and limited resources for prevention and care promote the spread of the virus in these countries (The status... 2000).

In North America, Western Europe, Australia, and New Zealand the principal modes of transmission are through homosexual and bisexual intercourse, intercourse with a drug user, and intravenous (iv) drug use. Heterosexual transmission makes up a small yet growing percentage of the cases. Adult males constitute most of the cases while the proportion of women with HIV infection is growing all the time. Consequently there is no marked paediatric epidemic. The countries within this pattern have advanced medical facilities to diagnose HIV infection and adequate economic resources to provide palliative care for those infected. Control of infection through blood transfusion has been effective since the mid 1980s.

In Asia, rates of infection are generally at a clearly lower level. They reach two percent or more of the adult population in only three countries: Thailand, Cambodia and Myanmar (The status... 2000). In many of the area's densely populated countries the current prevalence is less than 1%. There are, however, evidence that our understanding of the HIV epidemic based on currently

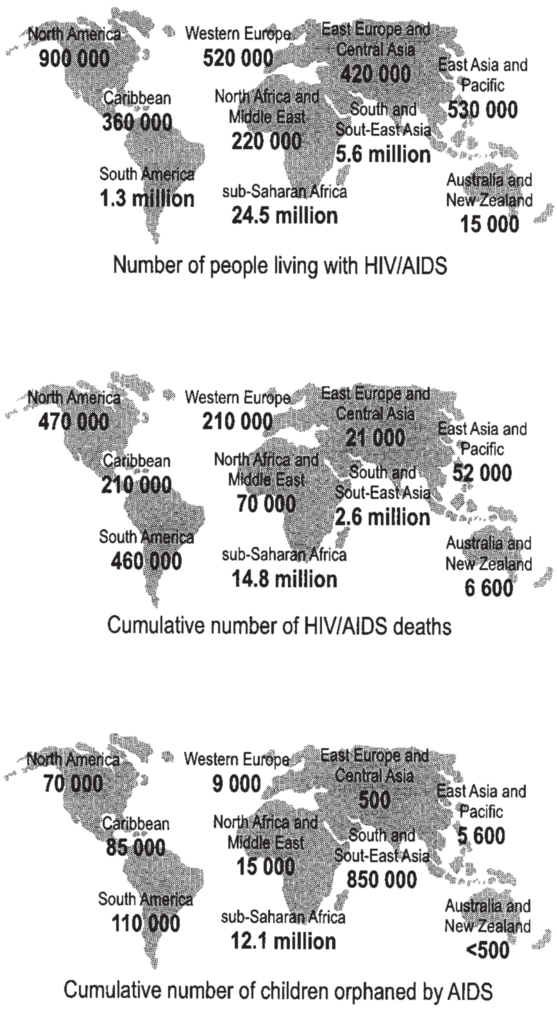

Fig. 2. Global estimate of people living with HIV/AIDS, cumulative number of HIV/AIDS deaths and cumulative number of children orphaned by AIDS, end of 1999.

available prevalence statistics e.g., in India have little to do with the true situation, and that both incidence and prevalence are much higher than anticipated at least in India's biggest cities. Two of the region's countries – India and China – together have a population that is over one third of the world's population and thus the potential for an accelerating epidemic is almost immeasurable (Ramasundaran 2002).

In Eastern Europe, Russia, and other parts of the former Soviet Union, the HIV epidemics continue to be mainly concentrated in iv drug users. Most HIV infected people are found in the largest cities although cases are increasingly found in all administrative regions in Ukraine, Russia, Belarus, and Moldova (Löytönen 1995, 1998; The status... 2000). The overall incidence figures have been smaller than in Western Europe. However, quite recently there have been marked outbreaks in Kaliningrad and Moscow among several thousand iv drug users suggesting that there exists quite a significant potential for the worsening of the epidemic. The relatively scarce financial resources and the poorly organised health care systems in these countries cannot provide for the majority of the population the quality health care available in the industrial countries.

In the Middle East and North Africa, HIV infection was relatively uncommon in the 1980's. Currently, the number of people infected is increasing but due to lack of reliable data on prevalence very little in known of the epidemics. It can be anticipated that transmission has taken place through sexual relations (homosexual and heterosexual) or intravenous drug use, but the true transmission patterns cannot be defined with confidence. Diagnostic capabilities are often but not always poor in this area (The status... 2000).

In Latin America and the Caribbean, the epidemic is currently evolving from predominantly homosexual and bisexual to heterosexual transmission with a rather diverse picture of the epidemic. Rates are generally highest in Central America and the Caribbean where heterosexual spread of HIV is the predominant mode of transmission. In Haiti the current rate exceeds 5% – the only country with such a high rate outside Africa – and in the Bahamas the rate exceeds 4%. In South American countries, the epidemics are generally concentrated in sub-populations at highest risk, such as men having sex with men and iv drug users. The overall trends in the region seem to be similar to patterns of the epidemic in North America with somewhat more variation. For example, the increasing number of heterosexual transmission cases is reflected in a marked paediatric epidemic in Puerto Rico (Löytönen & Arbona 1996). As the HIV infection continues to penetrate the poor and less advantaged people of the region, the future epidemic here might soon resemble the situation in sub-Saharan Africa as regards the predominant modes of transmission – but not necessarily as regards the rates of infected people (Pan American... 1997). On the other hand, countries such as Brazil, Argentina, and

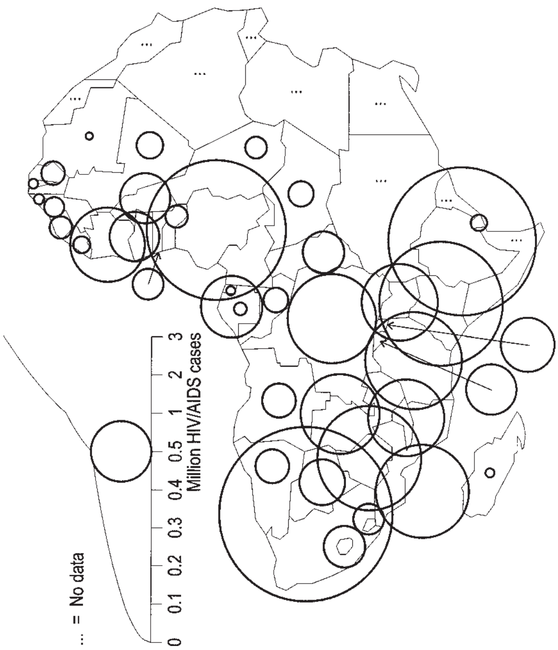

Fig. 3. Estimated number of people living with HIV/AIDS in Africa, end of 1999.

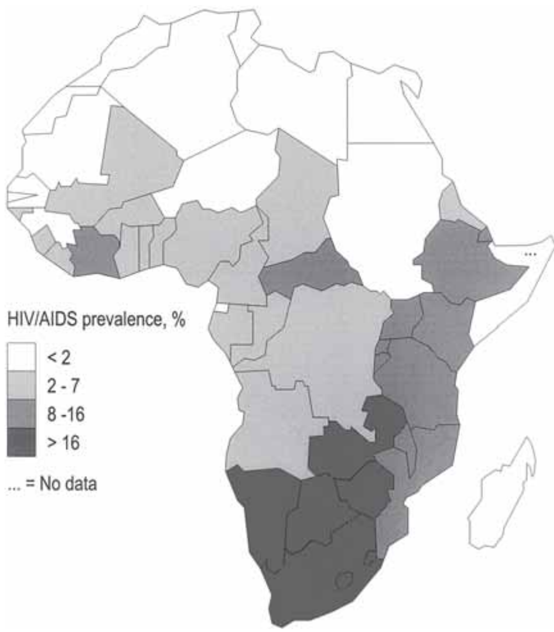

Fig. 4. Estimated HIV/AIDS prevalence in Africa, end of 1999.

Mexico have increased their efforts in providing proper care for those infected and in intervening the epidemic by education. As a consequence, statistics are showing decrease in AIDS mortality in the aforementioned countries.

Looking at the world map of the HIV pandemic, one can without doubt state that the situation is clearly the worst of all regions and continents in sub-Saharan Africa. The UNAIDS and WHO have estimated that there are currently 29.4 million adolescent and adult people infected with HIV. The geographical distribution of the cases is rather uneven throughout the continent (Figs. 3 and 4). While the first major epidemics occurred in central and eastern African countries, the epidemic is now the worst in the southern part of the continent. During the 1990s in South Africa, infection rates among the adult population increased from less than 1% to ca. 20% – an increase in its own class. Looking at the infection rates on the map, other countries that have equally high rates are Namibia, Lesotho, Swaziland, Zambia, and Zimbabwe. The situation is almost as bad in Ethiopia, Uganda, Kenya, Tanzania, Mozambique, Central African Republic, Togo, and Ivory Coast. With two exceptions, the prevalence rates are on a clearly lower level in West Africa. In sub-Saharan Africa the HI virus is spread predominantly by heterosexual intercourse. The male to female ratio is about 1:1. The high incidence of infection among women of reproductive age has created a paediatric epidemic with far-reaching consequences (The status... 2000; Matshalaga & Powell 2002; Morgan et al. 2002).

Forecasting – how and what

Epidemiological forecasting and spatial analysis of the diffusion of contagious diseases are essential methods for monitoring and controlling of epidemics. It involves both geographical and mathematical modelling. In addition to different geographic and demographic variables, the data needed in such modelling deals with disease-specific factors providing fundamental information for estimating the necessary parameters. In most diseases these parameters are well known, or can be reliably estimated from existing data or can be obtained by analysing a representative sample of case histories. Based on such data, modelling of the growth curves and the spatial diffusion processes can be done with a high degree of accuracy.

When attempting to model the HIV epidemic, however, the situation is somewhat more complicated. While clinical, virological, and immunological research has progressed rapidly, epidemiological research on HIV has been riddled with data-related problems. Estimates of the growth of the HIV epidemic have proved to be far less successful than one might wish. The conclusion is practically the same whether one looks at forecasts provided by applying explanatory (multivariate) models or autoregressive (univariate) models.

Some attempts have been made to estimate the growth curve of AIDS cases or HIV carriers in a given population by using simulation techniques. Although these studies have provided valuable information about the epidemiological parameters needed in the modelling, they have mostly focused on limited geographical areas or strictly defined subgroups of the population and thus not succeeded in providing very reliable forecasts of the future course (geographically or demographically) of the epidemic at large.

The problems in forecasting the HIV epidemic are mostly due to the virological features of the virus, and its connection to various forms of human sexual behaviour i.e., to some of the most hidden sides of human life. Many of the fundamental disease-specific parameters are still only partly known and understood. These include, among others, the mean and group-specific incubation time, the rate of risk associated with the different ways of transmission, the number of partners and the frequency of sexual intercourse and its variation in the heterosexual population, and the exact role of transmission cofactors such as genital ulcers.

The data problem is also due to the fact that in most countries there are no systematically compiled data available about the true HIV prevalence, although the need for such data is generally recognised. As a result, most attempts at forecasting the HIV epidemic are based on data covering only symptomatic AIDS patients. From the forecasting point of view, the primary focus should always be on analysing the spread of the virus, not merely the statistics of the clinical development of the infection – which again varies much depending on several factors. These include, among others, the availability of clinical treatment, the socio-economic status of the patients, and the quality of the health care system in general.

Attempts to use the traditional epidemiological models has led us to a dilemma in which the accuracy of the data does not meet the requirements set by the models. This is not to say that work done in this field is not valuable. Quite the contrary. Every bit of new information brings us closer to the date when we will able to produce reliable forecasts using even the most demanding and complex methods (for a review, please see Anderson 1989; Bremerman & Anderson 1990; Löytönen 1991, 1994a, 1994b; Thomas 1992, 1996, 1999; Low-Beer & Stoneburner 1997; Auvert et al. 2000).

When will the growth level off in Africa

As regards the HIV epidemics in Africa, the lack of reliable data is a key problem when planning of modelling and forecasting the detailed geographical diffusion or distribution of HIV/AIDS cases. The recent estimates on country-level produced by UNAIDS and WHO (The status and... 2000; AIDS epidemic... 2003) are without doubt the best and most reliable ones currently available and in my view they should be used as the base for making plans of how to most efficiently intervene the epidemics and of how to best organise the scarce resources available for health care. The numbers are based on several small sets of data obtained from many independent studies and surveys throughout the continent and analysed by experts (the Delphi method) to deliver as reliable forecasts on country level as possible given the conditions.

Geographically speaking the picture is very broad and provides little if any advice of what are the spatial diffusion patterns within these countries not to mention even more detailed spatial units. Should such modelling and forecasting be possible, the results would provide one step further planning of how to intervene the epidemics. On the other hand, one could also ask whether it is reasonable even to attempt such modelling and forecasting with the lack of sufficiently good data. Even the simplest autoregressive forecasting methods would be based on estimated parameters if applied in sub-Saharan African countries.

There is, however, one important question that should be addressed from the forecasting point of view. Let us return to the opening point of my paper regarding the basic population dynamics. In the industrial countries, there are already clear signs that the growth curves of the HIV epidemics are beginning to level off. In other words, given the socio-economic and other environmental conditions in most industrial countries of the world, a balance between the HIV epidemics and the population seems to be emerging. The key question, thus, is what will be the prevalence rate level once the balance has been achieved in those conditions prevailing in each region or country.

If – as it seems – the prevalence rate levels in the industrial countries remain more or less below 1%, the epidemics can be seen to be under control to a certain extent at population level. Subgroups of known high risk behaviour such as iv drug users and men who have sex with men without protection will of course demonstrate much higher prevalence rates. But in most countries these subgroups are marginal and will have lesser impact on how the epidemics of the overall population will develop.

In sub-Saharan Africa, we are already hitting prevalence rate levels that are horribly high compared with virtually any other part of the world. There are, furthermore, no significant signs of the growth levelling off in most of the countries. The few exceptions are Uganda that has managed to bring down its estimated prevalence rate from 14% to 8% with a strong prevention campaign, and Zambia where there are some encouraging signs of alike development. If the growth in sub-Saharan Africa continues with current speed – and this is most likely based on what we know of the predominant modes of transmission, how limited resources are in Africa, and by looking at the most recent estimates of the current trends of the epidemics – then the levelling off will happen at a level leaving little if any hope to many of the countries in sub-Saharan Africa. Undoubtedly, there will be great geographical variation in Africa from country to country, within countries, and between different groups of people according to their socio-economic, ethnic and behavioural status. But even if some countries and regions succeed in intervening in the epidemic and forcing the growth to level off at lower level, continent-wide the level will be much higher than elsewhere (Ojo & Delaney 1997; Gilks et al. 1997; Tarantola & Schwartlander 1997; Bouckenooghe & Shandera 1999) (Fig. 5).

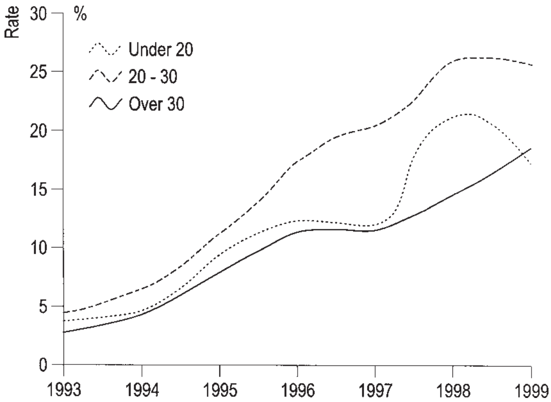

Fig. 5. HIV prevalence by age, South African antenatal clinics, 1993–1999.

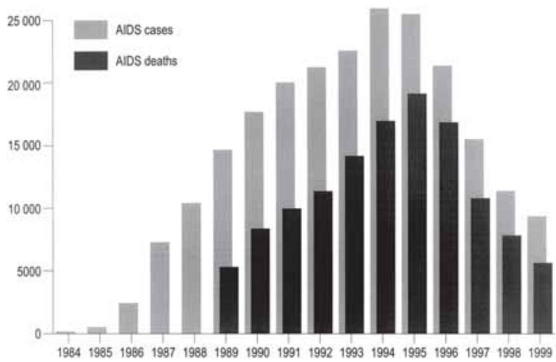

Fig. 6. AIDS cases and AIDS deaths in the WHO European region since the beginning of the epidemic. The use of highly active anti-retroviral therapies since 1995 have significantly reduced AIDS mortality.

Is there hope for sub-Saharan Africa

In industrial countries, the use of highly active anti-retroviral therapies since 1995 have reduced AIDS mortality significantly (Fig. 6). Such treatment of HIV infected individuals is very expensive, especially since monitoring and therapy is required throughout the germination period which with currently available drugs may be tens of years. The rich industrial countries may well be able to cope with the costs of the HIV epidemic

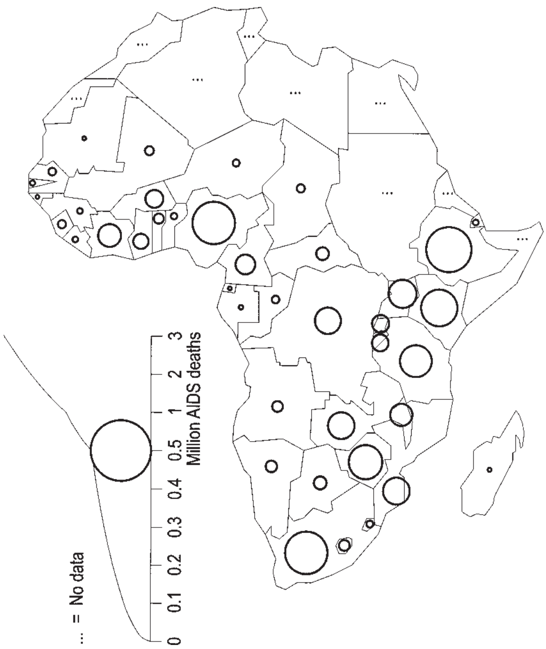

Fig. 7. Estimated number of AIDS deaths in Africa in 1999.

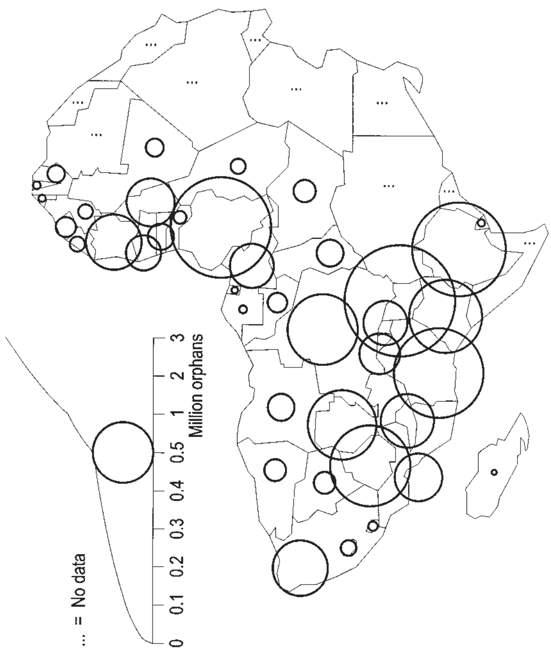

Fig. 8. Cumulative number of children orphaned by AIDS, end of 1999.

especially now when the growth curves are levelling off at a manageable level. But the situation in Africa is far more difficult. The treatment of HIV infected people is already exhausting the limited resources available for health care. Little is left for any attempts at controlling of the epidemic by means of educating people. It is already clear that AIDS mortality in Africa will soon rise to measures never seen before (Fig. 7). This will not only leave millions of orphans, but strike hard and deep in the societies through loss of work force in their best age (Figs. 8 and 9). The gap is enormous between the poor and rich countries of their chances of overcoming the economic and social problems raised by the HIV pandemic (De Kock et al. 2002; Rankin 2002).

The worldwide campaign to eliminate smallpox provides an interesting point of comparison for the HIV pandemic. The campaign was successful because the basic costs were low, the project gained broad international acceptance and the vaccination procedure did not require any advanced professional skills. Such a campaign could in principle be mounted against the HI virus once a vaccine has been developed. Despite significant efforts such vaccine is still far away in the future. And current information nevertheless suggests that any vaccine that might become available is likely to be an expensive preparation even by the standards of the industrial countries and it may require advanced medical techniques and highly skilled health care staff for its administration.

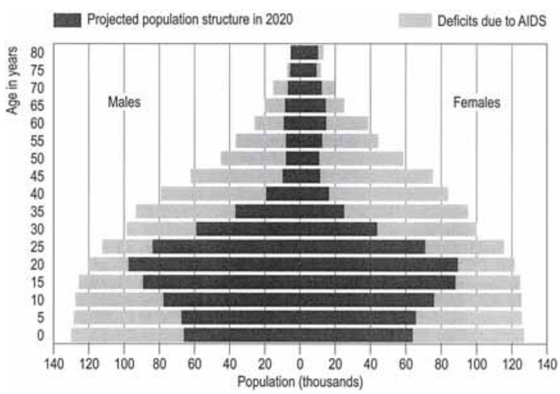

Fig. 9. Projected population structure with and without the AIDS epidemic, Botswana, 2020.

Would it be perceivable to think that the industrial countries financed a campaign of the same magnitude as the smallpox campaign? This is hardly the future unless the costs of treatment per individual HIV carrier come down to a manageable level. With currently available highly complex and expensive treatment such a campaign is not a likely option.

Could the worsening HIV epidemic in Africa and perhaps in other developing areas – especially in the densely populated countries such as India – pose a serious threat to the populations in the industrial countries and consequently force the rich countries to launch a campaign? Even a cautious evaluation of the situation suggests that it is quite possible that the growing population potential of the developing countries will eventually result in increasing migratory flows exerting pressure on the borders of the industrial countries – indeed there are already many signs of the attractiveness of these countries in the eyes of people living in the developing countries. As long as the costs of the campaign exceed the expected benefits, political will needed for such a campaign is hardly achievable.

Returning to the simple principle of population dynamics, the HIV epidemics in Africa and elsewhere will eventually level off and begin to oscillate around a mean value depending of the socio-economic and other environmental factors. We already now that this mean will be significantly higher in sub-Saharan African countries than e.g., in industrial countries. Unless significant scientific breakthrough in developing new cheaper drugs or a working easily administered and cheap vaccination materialises or a global political will materialises quickly, no real options for intervening the HIV epidemics in Africa can be seen in the near future. This means that most African countries will suffer from colossal human, economic and intellectual losses in the near future (Fig. 10). What will happen after that in sub-Saharan African countries is beyond all reasonable forecasts and will remain to be seen by the next generation – with or without hope.

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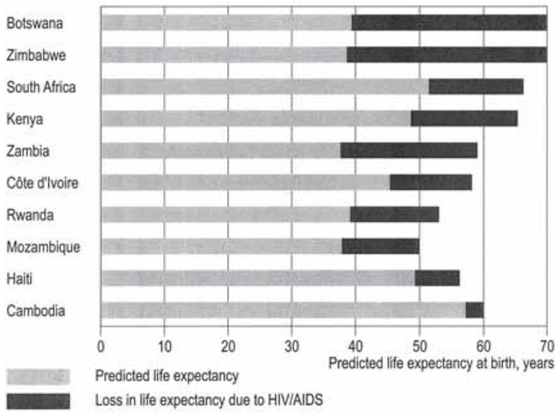

Fig. 10. Projected loss in life expectancy in selected countries due to HIV/AIDS in children born in 2000.

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