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POPULATION, AGRICULTURE AND THE FUTURE ENVIRONMENT IN SUB-SAHARAN AFRICA

Barbara Boyle Torrey

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The inexorable growth in the Sub-Saharan African (SSA) population in the next 40 years will complicate agricultural solutions that are developed for today's problems. Even assuming that fertility rates drop steadily, the numbers of people to feed will double by 2050. They will also be older than today's population, more urban and more demanding of their agricultural systems. In turn, the decisions made about how the agricultural systems will respond to the growing population will have substantial effects on the environment of Africa.

This paper includes:

- A brief discussion of the broad population changes in Africa from 1950 to today. These changes vary by region, but are impressive in aggregate.
- Comparisons of the Food and Agriculture Organization's (FAO) estimates of current food supply in Africa with what would be required to adequately nourish its current population;
- A brief discussion of future population and caloric requirements trends out to 2050. The requirements will not only be determined by the number of people

who will be alive 40 years from now, however. They will also be determined by how old the population is, their gender and whether they live in urban areas where they are less active than in rural areas.

- A summary of the implications for the agricultural systems of the future caloric requirements and the impacts that different choices will have on the African environment.

This paper uses aggregate macro data from multiple sources. It is a thought experiment sketching the rough outlines of possible agricultural and environmental futures. Because of the nature of the data and analysis this paper is neither definitive nor robust. But what thought experiments can do is raise future issues that should be pursued with better data and in-depth analysis.

I. Population, Nutrition and Biological Caloric Requirements: 1950-2005

In 1950 Sub-Saharan Africa had a similar number of people as North America and a growth rate that was only slightly higher (2.1 percent per year vs. 1.8 per year). But in subsequent years the African annual population growth rate accelerated, peaking at 2.8 percent between 1980 and1990. And as a consequence today's African population is more than twice the population of North America. Eight hundred million people now live in Sub-Saharan Africa and 43 percent of Africans are children under the age of 15.[1] (Chart 1)

Three of the four major regions of Sub-Saharan Africa have had explosive population growth rates. Central Africa is growing the fastest at an average annual rate of 2.8 percent a year; Western Africa is growing at 2.7 percent, and Eastern Africa is growing only slightly slower at 2.5 percent annually. Only Southern Africa, which had the smallest population to begin with in 1950, is growing at the much lower rate of 0.8 percent a year.[2] These historically large population growth rates are in large part caused by the substantial drops in mortality since 1950, which have not been matched by similar drops in fertility.

The quality of African demographic and health data is neither as bad as most people assume nor as good as industrial country researchers are accustomed to using. The population estimates are based on multiple sources of data and indirect estimates, the most important of which are the decennial population censuses that are used for the sampling frames for intracensal surveys. The most important intracensual population surveys are the periodic Demographic and Health Surveys that provide more in-depth data about subsets of the population. The disadvantage of demographic data in Africa, however, is that most come from cross sectional surveys. Therefore, only correlations among the data can be observed. Conclusions about causality must wait for the longitudinal surveys that are now beginning in selected countries.

In Sub-Saharan Africa the prevalence of under nutrition is the highest in the world. In 2000 under nutrition in the total population ranged from over 56 percent in Central Africa, 37 percent in Eastern and Southern Africa and 15 percent in Western Africa.[3]

(Chart 2) Undernourished pregnant women are especially vulnerable to producing either low birth weight or malnourished infants. And both kinds of infants are at much higher risk of death than infants from well-nourished mothers. Despite the high prevalence of malnourished mothers and low birth weight children, however, 90 percent of infants survive in Africa today. They however, show the effects of under nutrition with an estimated 40 percent of African children under 5 being stunted in 2005 (defined as having a height lower than two standard deviations for their age).[4] (Chart 3)

It is a cruel irony that infant mortality rates can decrease while at the same time the stunting of surviving children increases because there isn't enough food to feed the survivors. Since 1986 there are at least eight African countries where infant mortality has improved but stunting has worsened (Benin, Mali, Burkina Faso, Guinea, Malawi, Niger, Rwanda, and Zambia).[5] Children who are stunted by age two can not make up for their early nutritional deficit later in life. And the early nutritional deficit has other more pernicious long term consequences that undermine the long term development of Africa.

While under nutrition is a major, chronic issue in Africa, there are already the first signs of a transition to over nutrition in Africa's urban areas. The Demographic and Health Surveys have documented the trends in weight gain over time especially for urban populations with access to subsidized and imported food. In Tanzania, Kenya and Ghana the number of overweight people has been increasing since the 1990s; prevalence today is now between 13 percent and 16 percent in these countries.[6] Subsidized foods, especially in the urban areas, and the availability and preference for foods with higher fat

and sugar content are characteristic of this nutritional transition that is happening in many countries.[7] This transition in nutrition will directly affect the health and epidemiological transitions in developing countries by creating a new set of health issues and shifting the morbidity and mortality profiles of the urban populations towards non-communicable diseases, such as strokes and heart attacks. With forty percent of the populations of many Africa countries still undernourished, however, the challenge is to improve their nutrition without encouraging over nutrition.

Comparison of Current Food Supply and Biological Requirements for Food. The high prevalence and long persistence of under nutrition in Africa is not intractable, fortunately. FAO estimates the dietary energy supply in terms of calories per person per day available from the estimated crops harvested by country and year.[8] These estimates are necessarily imprecise because of the nature of the data, which are based on assumed size of the harvest for different crops and estimated number of calories each crop represents. There are many reasons why harvested calories do not represent what is available on the ground over a twelve month period. Wastage of food both in storage and in transit is one important issue. But the estimate of dietary energy supply (harvested calories) is useful in judging the theoretical supply of food available in Sub-Saharan Africa.

The 2001-03 FAO estimated Dietary Energy Supply of calories per person per day in each country can be multiplied by the number of people in that country to estimate the gross number of calories available by country per day and then aggregated by country to provide an estimate for Sub-Saharan Africa. (Table 1 shows that African harvests in

2001-2003 produced approximately 1.421 Billion calories per day according to the FAO's estimates of Kcal/cap.) The FAO estimate of harvested calories raises the immediate question of how many daily calories in aggregate do the people of Africa require to be healthy.

This concept of caloric requirement is fundamentally different from food demand because caloric requirements are based solely on biological requirements whereas food demand is based on prices, tastes and availability, in addition to biology. The measure of caloric requirement used in this chapter is based on biological requirements for a healthy individual and therefore assumes no under nutrition nor obesity, and does not take into account changing demand for different kinds of food, such as more meat and imported luxuries or deficits in micronutrients. Urban populations' demand for more and different kinds of food are not reflected in caloric requirements. But the estimates in this chapter do reflect the differences in required calories by age (adults require more calories than children), gender (men require more than women), and by activity level.

Periodic estimates of daily caloric requirements are done by both the FAO (Food and Agriculture Organization) and the U.S. Institute of Medicine (IOM) of the U. S. National Academy of Sciences.[9] [10] Both FAO and IOM estimates differ some in the details, but are similar in the aggregate. The IOM estimates (which this chapter uses)are based on the biological requirements of individuals of median (U.S.) height and healthy weight associated with the median height (a body mass index of 21.5 for adult females and 22.5 for adult males). Most Americans are now heavier than this assumption would imply, but

the estimates continue to be based on healthy, not current, unhealthy body weights. The IOM estimates also vary for sedentary (light physical activity), moderate (1.5-3 miles of walking a day) and high activity levels (more than three miles a day). The calculation of the average caloric requirement in Africa made in this chapter assumes that the active caloric requirement is a minimum needed for Africas in rural areas and that the moderately active caloric requirement is the minimum needed for urban populations. Few Africans have a sedentary life style and therefore the caloric requirements for sedentary activity are not used. (Appendix I has more information on the IOM estimated caloric requirements by age, gender and activity level.)

Applying the IOM estimated caloric requirement to the UN estimates of Sub-Saharan Africa population in 2010 disaggregated by age, gender and urban/rural residence results in an estimate of 1, 399 Billion calories needed per day for the people of Sub-Saharan Africa. (Table 2) Therefore, caloric requirement based on an American standard for today's African population is approximately the same as FAO's estimate of caloric supply from African agriculture (98.5 percent). However, these estimates, like the FAO estimate of calories available per day in Africa, imply a precision that is impossible given the nature of the numbers. These estimates of caloric supply and requirements are simply macro estimates based on multiplying aggregate data from different sources. Other problems with the calculations include the fact that the caloric requirement estimate is based on median American activity levels that surely are modest compared with African levels, but no estimates have been done of African requirements. Moreover, the estimated harvested calories are larger than the availability of calories because of wastage

in storage and inadequate distribution of the existing calories effectively. For these and other reasons these estimates should only be used as a thought experiment rather than as a completed analysis of the issues. Still, since the estimates of supply and requirement for calories are a similar order of magnitude, they hint that the problem of under nutrition in Africa today may be less the result of too little supply than a misallocation of the caloric supply of food that is harvested.

II. Future Population Trends and their Implications for Food Requirements

Sub-Saharan Africa's population, which is growing at 1.8 percent a year, will put relentless pressure on the agricultural system in the future. The momentum of the past population trends will have a powerful effect in the future because the infants and children of today will be the parents of tomorrow. The size of the future generation of parents is already determined and their fertility will determine the size of the subsequent generation.

Fertility represents the biggest uncertainty about the estimates of future populations. A demographic transition from high fertility and high mortality to lower mortality and lower fertility within a population has occurred in most countries around the world. A decline in fertility historically occurs after infant mortality rates decline, but the lag between the two declines varies widely. In Sweden death rates started to drop in 1820 because of the agricultural revolution in the 18th Century, but fertility didn't begin to decline until 40 years later.[11] In Mexico death rates began to drop in 1920, but fertility didn't start to drop until 55 years later. In Mauritius the lag between the start of the death

rate decline in 1945 and the beginning of the drop in fertility was 15 years. Africa's mortality rates began dropping 50 years ago and fertility rates began to decline 25 years later. (Chart 4) Fertility declines are correlated with increases in education, urbanization, age of marriage, and contraceptive use, all of which are correlated with each other.[12] But even though education, urbanization and age of marriage are all increasing, many African fertility rates are declining slowly and some have stalled. Each country has responded differently to drops in mortality and changes in other factors because initial conditions vary widely among African countries, which help create varied responses.[13] [14]

One indicator of possible future decreases in fertility is the responses of African women today when they are asked about their ideal number of children. The Demographic and Health Surveys have been asking the question for years in their periodic national surveys. Because they are cross sectional surveys it is impossible to observe whether the ideal predicts the future number of children a particular woman will have. But patterns of responses can be correlated with other demographic characteristics to give at least suggestions about the ideal future. In the 1990s African women who had an ideal number of children lower than the current fertility in their country tended to be younger (women ages 20-24 wanted one child less than their mother's generation who are 40-44); better educated (women with high school education wanted one children less than those with only a primary education) and more urbanized (urban women wanted one child less than rural women). However, there are many reasons why women may not reach their ideal number of children, including unwanted fertility, sex preferences and lack of contraceptives.[15] As a result the ideal number of children a woman says she wants may

foreshadow the direction of change in future fertility, but it is very imprecise in estimating the magnitude of the change.[16]

The UN's population projections assume that there will be a steady decline in fertility rates from now to 2050. And the data on ideal number of children suggest that their assumption about the direction of change is almost certainly right over the long term. However since fertility declines have stalled in several African countries the UN assumption about steady declines in fertility is optimistic. Because of the uncertainty in the future of fertility changes the UN has projected three different fertility scenarios that reflect high, medium and low fertility assumptions. Under the median fertility assumption the future populations in Africa will almost double between 2010 and 2050. (Chart 4) Therefore, the implications for agricultural development in the next 40 years become more complicated.

Projections of the Caloric Requirements for Future African Populations. Increasing populations inevitably translate into increasing demands for food. The International Food Policy Research Institute has developed a model that analyzes baseline and alternative scenarios for global food demand, supply, and trade.[17] Demand is defined as a function of prices, income and population growth so it is not the equivalent to the biological demand concept used in this paper. But it is important to understand the trends such a model projects. The recent projections of the demand for food suggest that the consumption of cereals in Sub-Saharan Africa will slow from 3 percent a year in the last 30 years to 2.5 percent in the next 30 years. At the same time meat consumption is

projected to increase from 2.6 percent per year in the last 30 years to 2.9 percent in the next 30 years.[18] These projections partly reflect the absolute increase in populations, but decreases in population rates of growth, decreases in under nutrition and changes in tastes from cereals to meat. These projections, however, assume that demand is driven by prices, markets, and preferences, all of which are harder to predict many years into the future than biological requirements.

This paper projects biological food demand for a well-nourished African population as explained in Section I above. If we assume that the biological requirements for future individuals are similar to those of today, then it is possible to estimate the total biological requirements needed by using population projections disaggregated by age, gender and urbanization. (The caloric requirements using IOM estimates applied to the United Nation's long term demographic projections for Sub-Saharan Africa are shown in Table 2.) The increase in caloric requirements is similar to the increase in population because of the net offsetting effects of the increase in urban population and the change in the age structure. Urban population goes from 37 percent of Sub-Saharan African population in 2010 to 60.5 percent in 2050 (under both medium and low projections). Increasing urbanization will tend to decrease the requirement for calories because urban physical activity requires fewer calories than the higher physical activity in rural areas. (In reality, much of the obesity in Africa occurs in urban areas because although the activity level is lower than in rural areas the demand for food is not.) The estimated decrease in the urban caloric requirement per capita, however, is likely to be offset by the change in age structure by 2050. By 2050 the population that is 9 years old and older will grow from

70 percent of the population to 80 percent under the medium projection. This age group requires approximately 70 percent more calories per capita than the 0-8 age group. Therefore, although the magnitude of the change in urbanization is much larger than the change in the age structure, the caloric implications of the age structure change is much more important. Therefore, the age structure change more than offsets the decrease in the requirements for calories from urbanization. (Table 2) Total daily caloric requirement for a healthy Sub-Saharan population increases 108 percent between 2010 and 2050 for the median population projection; in the low population projection caloric requirements increase 83 percent by 2050. (A previous study, which also calculated the effect of demographic changes on food requirements using the FAO instead of the IOM caloric requirements, found similar results. It also examined the effects of demographic change on food requirements in Africa from 1995 to 2050 and estimated that food requirements would increase slightly more than population growth, with the effects of urbanization offsetting the increasingly older age structure.[19])

Although it has been mentioned before, it is important to understand the biases in these calculations. Biological requirements are almost certainly an underestimate of what future populations are likely to demand. As Africa continues to urbanize its populations are likely to eat more food rather than less because it is available and in many cases is subsidized. They are also likely to eat more animal products, which are calorie intensive. Therefore, caloric biological needs should be considered a minimum or base line rather than a medium projection of future food needs.

Another condition that will affect the harvested supply of calories in the future, but that has not been reflected in the current estimates, is the impact of climate change on African agriculture. Recent estimates of the effect of climate changes suggest that the amount of arid and dry semi-arid areas in Africa is likely to increase between 5-8 percent by 2080.[20] Thirteen African countries are likely to lose cereal-production potential by the 2080s; 10 countries are likely to gain. The net changes in cereal production potential for sub-Saharan Africa are projected to be losses of up to 12%. Although the projections are based on assumptions about climate change and the future, it suggests that improving African agriculture to fully meet the demands of its population will be a moving target that will be buffeted by more than demography.

III. Environmental Impacts of Increasing African Agricultural Productivity

The doubling of the biological requirement for calories in the next 40 years will put considerable pressure on African agriculture to increase its production. How it decides to do that will have important environmental consequences both on the local biome and in the larger biosphere. Agriculture has been changing the African environment for thousands of years.[21] But today with increasing population and decreasing environmental quality in Africa the stakes have changed. Now Africans have to shrink agriculture's substantial environmental footprint while eliminating malnutrition for a population that will more than double in the future. The challenge is clearer than the solutions.

Before WWII most of the increases in agricultural productivity had come from the expansion of both land and labor and the decrease in fallow periods.[22] This was true not only for much of the land in Africa, but for the rest of the world. Today much of the land, especially the fertile land, in Africa is already either used for cultivation or for pasture.[23] In East, Central and West Africa more than 40% of current land is used for cultivation and pasture. In South Africa it is 55%. That means that any future expansion in cultivation is likely to be on more marginal land such as hillsides or by deforestation of tropical forests. These are places where the productivity is likely to be less and the environmental damage more. For example, sixty percent of the tropical African forest cleared between 1990 and 2000 has gone to agriculture.[24]But despite these increases in agricultural land the growth rate in crop and livestock production has not kept up with population increases until very recently. (FAO 2003-4). This is one of the reasons that under nutrition has been such a chronic problem in Sub Saharan Africa.

Population growth does not always lead to an expansion of cropland and deforestation in Africa, however. Ester Boserup's seminal study in 1965 suggested that increases in population density were more likely to lead to better management of land and water resources and the intensification of agriculture in general.[25] For example, in Northern Nigeria where population increased very rapidly between the 1960's and 1985 tree density had doubled west of Kano and had remained constant east of the city.[26] But better management of the environment is not an inevitable outcome of increased population density. Between 1978 and 1996, when population density was increasing in other parts of Nigeria, deforestation occurred at a rate of 470,000 ha a year.[27] Whether

farmers respond to growing population density and demands by preserving their environment and the fertility of the soils or degrading both depends on the options that the society, economy and science offer them.

In the last 10 years, the growth rate in agricultural GDP per capita has begun to improve.[28] This occurred at the same time as better macro economic policies were adopted. It is also at the same time as an increasing number of agricultural experiments demonstrated new technologies and seeds that can improve productivity without necessarily increasing the need for more land. This had been a development that has already occurred in other parts of the world. Since 1960 world agricultural productivity has increased 300 percent with only a 10% increase in total cultivated land for cereals.[29] Africa today has perhaps the largest potential for increasing its agricultural yield on current land of any continent in the world because it has yet to enjoy the broad progress that many of the other countries gained during the Green Revolution. Increased yields can be realized without more deforestation if the potential yields in the demonstration projections can be partly realized. (Of course this intensification of agriculture will bring other environmental issues that will be mentioned below).

Today gaps in yields per hectare exist for virtually every crop in Sub-Saharan Africa and in every region. Some of these potential yields are achieved by using different ways of tilling the soil (zero tillage), some with different technology (the Broad Bed Maker used in Ethiopia to replace the less efficient traditional plough) and improved seeds (quality protein maize in Nigeria). Table 3 and Chart 5 show the potential increases in cereal

yields that were achieved on demonstration plots compared with the average yields of comparison farms. There have also been similar potential yields found for other crops such as rice (using the NERICA new rice for Africa), cowpeas and soybeans in selected countries. The possibilities of major increases in yields for most crops in most countries suggest the potentials in intensification rather than extensification of agriculture.

Past experience has shown that it is unrealistic to achieve the full potential yields that have been realized on experimental farms. A more realistic assumption may be that about 80 percent of the demonstrated potential yields can be realized.[30] Chart 6 compares the 80 percent of the potential yield increases in maize with the percentage increase in the calorie requirements that will be required by 2050. If it is assumed that the potential yield increases in maize could be achieved in other crops then 4 of the 7 countries examined could have agricultural increases that exceed the caloric increases required, including the two largest countries in Sub-Saharan Africa, Nigeria and Ethiopia. Two others, Burkina Faso and Ghana would meet more than 80 percent of the 2050 requirements in calories. Only Mali of the seven countries shown would be below the future caloric requirements.

If there were similar increased yields for other crops and other countries and if there were better functioning food markets to distribute food from the food surplus countries to those with food deficits then it suggests that Sub Saharan Africa may not only be able to meet the caloric needs of its people in 2050, but that they could do this without significantly increasing the amount of land under cultivation.

It is worth repeating that this thought experiment is based on some mighty assumptions:

- Agriculture in Africa today is producing roughly enough to meet the caloric requirements of its current population. If this is true then the current levels of under nutrition are more the cause of distribution of harvested calories than the scarcity of food.
- African population will double between 2010 and 2050. This, of course, will be dependent on the future fertility rates.
- Eighty percent of current experimental agricultural yields could be achieved on current agricultural lands in the future.
- The biological caloric requirements are less for urban populations than rural ones. However, preferences may dominate biology, regardless of the assumption in this paper.

This thought experiment does not take into account changing tastes that will eventually demand more meat and less cereal in the future. (Livestock requires much more grain to produce the same amount of calories and therefore increasing demand for meat will push the demand for more cereal crops up. But there are also a number of productivity increases in livestock raising that have been achieved in demonstration projects that are not discussed in this paper.)

It is much easier to demonstrate the gap in agricultural yields between the average and the experimental farm than to close it. It will require considerable improvements in storage systems, infrastructure to get the calories to market, credit institutions so that farmers can buy the fertilizer and seeds they will need and an infrastructure to ensure that crops have water. These would be no small accomplishment. The potential yields shown in Table 3 and Chart 6 will require a fundamental restructuring of the markets and governance. But it would have an environmental dividend.

Deforestation that has been a major environmental problem of the past agricultural growth in Africa would not be inevitable. It, however, would be replaced by other environmental issues that come with the intensification of agriculture. These include soil degradation if it is over watered, the depletion of soil nutrients if it is under fertilized, and polluted runoffs from the agrochemicals in the fertilizer.[31] There may also be the loss of crop genetic diversity and an increase in zoonatic diseases if livestock is also more intensively raised. These are environmental problems that have already been confronted by a number of other countries who have been farming more intensively for many more years than countries in Sub Saharan Africa. These are environmental problems that are for the most part reversible, unlike the environmental problems that come from extensification such as deforestation with its loss of biodiversity and erosion.

IV. Policy Implications and Research Needs

Today Africans are largely dependent on their domestic agriculture to meet their food needs. This is, in part, because of the limited tradability of the staples in their diet; it is

also because of the high transaction costs because of the lack of adequate infrastructure such as roads and markets.[32] These conditions are likely to improve in the next forty years, making it easier for African populations to satisfy their food needs from international trade. But until those improvements are made the requirement for food and adequate calories will have to be supplied more by African agriculture than international trade.

As Section I suggested, it is possible that Sub-Saharan Africa may be growing enough food today to supply its current population with its biological caloric requirements. But the presence of so much under nutrition means that the food is not efficiently distributed either spatially or temporally with some areas having too much food and being over nourished while other areas have too little food. The simultaneous existence of obesity in urban areas and under nutrition in rural areas within the same country illustrates this dilemma. Many people have suggested that a better market place for food would help to solve the distribution problems of food in Africa. The infrastructure required for functioning markets, however, includes expensive investments such as roads and communications network for prices, supplies and weather. Efficacy of investments and the sequence of investments are beyond the scope of this paper. But this paper does imply that research on these issues is critical to addressing current issues.

Improving current infrastructure, however, will not be enough to meet the challenges of a population that will double in size in the next 40 years. And because the population will be older it will require disproportionately more calories. The future population increase

and change must be addressed by increasing agricultural productivity to meet the caloric requirements of a growing and changing sub-Saharan African population. Most important is to do the agricultural research simultaneously with long term environmental research on the effects of the intensification of agriculture. This research will have to adapt previous research already done in other countries to the specific conditions of Sub Saharan Africa.

Increasing agricultural productivity will not only increase the amount of food available in Africa, it will also increase labor productivity, income growth and GNP growth.[33] If the agricultural productivity growth is larger than the population growth, then it may also decrease under nutrition even while the agricultural market infrastructure is improving. And it may also affect the population dynamics themselves. One recent study has suggested that increasing the use of modern crops in Africa by 50 percent will decrease the fertility rate by half a child.[34] Developing countries, which have adopted modern crops during the green revolution, have all seen decreases in fertility as rural incomes of farmers rose.

This paper has made no assumptions about the adoption of seeds that are genetically modified with cross species genes. The robustness, improved yields and better nutrition from some of those seeds have been even better than the seeds used in the demonstration projects referenced in this paper.[35] Although GMO seed varieties are used extensively in US, Canada, Argentina and China they have not yet been adopted in African with the exception of South Africa. This is because of the unknown potential risks of introducing

new varieties into untested environments. India has recently introduced Bt cotton and had a 79% average increase in 2002. This potential increase in yields from GMO seeds in one year has not been included in this paper. But they are potentially large enough to be seriously considered by African agricultural researchers to determine their suitability for African conditions. These kinds of yields plus the increased resistance to diseases suggest that the potential benefits over the next 40 years may be considerable when added to other potential improvements to the soil and technology.

This thought experiment helps think about the future rather than predicting its course. The assumptions are not specific to a selected country or biome. There will be environmental consequences no matter whether African agriculture intensifies or extensifies in the next 40 years. That is why it is so important that demographic and environmental research be integrated with the agricultural research. Realistic assessments of how much food African populations will need in the future will provide the goals needed for agricultural research to use in estimating the agricultural productivity that will be required for healthy populations. And how that required agricultural productivity is achieved will suggest the kinds of future environmental issues in Africa. But the attention to these overlapping research fields will require better data and more fertile minds than have been available historically on other continents.

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TABLE 1

SUB-SAHARAN AFRICAN CALORIES AVAILABLE PER DAY 2001-200
(BASED ON FOOD HARVESTED)

COUNTRY	Dietary Energy Supply (KCAL/CAP/ DAY)	NO. PEO (IN MILL)	TOTAL KCAL/DAY (IN BILL)
ANGOLA	2070	10.4	21.528
BENIN	2530	6.6	16.698
BOTSWANA	2180	1.6	3.488
BURKINA	2460	12.3	30.258
BURUNDI	1640	6.2	10.168
CAMEROON	2270	15.8	35.866
CAR	1940	3.6	6.984
CHAD	2160	8.7	18.792
CONGO	2150	3.5	7.525
COTEDIVOIRE	2630	16.4	43.132
DEMREPCONGO	1610	69.8	112.378
ERITREA	1520	4.3	6.536
ETHIOPIA	1860	65.9	122.574
GABON	2450	1.3	3.185
GAMBIA	2280	1.8	4.104
GHANA	2650	22.6	59.89
GUINEA	2420	9.3	22.506
KENYA	2150	30.8	66.22
LESOTHO	2620	2.2	5.764
LIBERIA	1940	3.2	6.208
MADAGASCAR	2040	16	32.64
MALI	2220	11	24.42
MALAWI	2140	11.6	24.824
MAURITANIA	2780	2.7	7.506
MAURITIUS	2890	1.2	3.468
MOZAMBIQUE	2070	19.4	40.158
NAMIBA	2260	1.8	4.068
NIGER	2160	10.4	22.464
NIGERIA	2700	126.6	341.82
RWANDA	2070	7.3	15.111
SENEGAL	2310	10.3	23.793
SIERRA LEONE	1930	5.4	10.422
SUDAN	2260	36.1	81.586
SWAZILAND	2360	1.1	2.596
TANZANIA	1960	36.2	70.952
TOGO	2320	5.2	12.064
UGANDA	2380	24	57.12
ZAMBIA	1930	9.8	18.914
ZIMBABWE	2010	11.4	22.914
TOTAL		643.8	1420.644

Sources: Dietary Energy Supply is from FAO Agricultural Produce 2001-2003.
Population estimates from PRB and the United Nations.

TABLE 2

CALORIC REQUIREMENTS FOR AFRICA'S FUTURE POPULATION

YEAR	TOTAL POP. (IN MILL)	URBAN POP. (IN MILL)	POP. 9+ (IN MILL)	TOTAL DAILY CAI REQUIRE. (IN BILL)
		MEDIUM POPULATION PROJECTIONS		
2010	866.9	323.4	605	1809.4
2015	971.5	386.7	688.2	2034
2020	1081	458.4	780.8	2273.4
2025	1103.6	539.5	880.1	2522.1
2030	1308.5	630.7	984.1	2776
2035	1424.4	729.3	1090.8	3031
2040	1539.6	836	1199.4	3283
2045	1652.3	948.4	1308.6	3528.7
2050	1760.7	1065.2	1416.6	3764.3
PERCENT INCREASE 2010-2050	103%	230%	134%	108%
		LOW POPULATION PROJECTIONS		
2010	860.1	320.8	605	1801.2
2015	952.2	379	688.2	2008.1
2020	1043.8	442.6	774.3	2218.2
2025	1135.7	513.3	861.6	2427.1
2030	1225.6	590.7	948.1	2629.8
2035	1310.7	671.1	1034.6	2821.3
2040	1388.6	754	1118.8	2997.8
2045	1458.1	836.9	1198.1	3155.4
2050	1518.4	918.7	1269.8	3290.7
PERCENT INCREASE 2010-2050	76%	186%	101%	83%

Sources: *The United Nations World Population Prospects: The 2006 Revision*, and Institute of Medicine of the Academy of Science, Dietary Reference Intakes, National Academy Press, 2005.

TABLE 3

COMPARISON OF AVERAGE AND POTENTIAL YIELDS FOR MAIZE AND WHEAT IN AFRICA

	Average (ton/ha)	Potential (ton/ha)	Ratio of Potential Yield to Average	
			100% of Potential	80% of Potential
Burkina Faso Maize 2000	1.1	2.7	2.4	1.9
Ethiopia 2000-2004 Wheat	0.7	2.4	3.4	2.7
Guinea 1999-2000 Maize	1.45	2.8	1.9	1.5
Ghana 1997-1999 Maize	1.48	3.6	2.4	1.9
Mali 1998-2000 Maize	1.61	2.8	1.8	1.4
Nigeria 2004/5 Wheat	1.3	3.9	3	2.4
Tanzania 1998 Maize	1.3	4.8	3.7	3

Sources: Burkina Faso, Ghana, Guinea, Mali: interAcademy Council, *Reaslizing the promise* and Potential of African Agriculture, Science and Technology Strategies for Improving *Food Security in Africa 2004. p.78.* Ethiopia: Feeding the Future, Newsletter of the Sasakawa African Association July 2007 p. 4. Nigeria: Feeding the Future Newsletter of the Sasakawa African Association May 2008; Tanzania: Sasakawa Africa National Association Profile, http://www.saa-tokyo.org.

APPENDIX

ESTIMATED CALORIE REQUIREMENTS (in Kilocalories) FOR EACH GENDER AND AGE GROUP AT DIFFERRENT LEVELS OF PHYSICAL ACTIVITY

GENDER	AGE*****	MODERATELY ACTIVE*	ACTIVE**
CHILD* **	2-3	1,000-1,400	1,000-1,400
FEMALE** **	4-8	1,400-1,600	1,400-1,800
	9-13	1,600-2,000	1,800-2,200
	14-18	2,000	2,400
	19-30	2,000-2,200	2,400
	31-50	2,000	2,200
	51+	1,800	2,000-2,200
MALE	4-8	1,400-1,600	1,600-2,000
	9-13	1,800-2,200	2,000-2,600
	14-18	2,400-2,800	2,800-3,200
	19-30	2,600-2,800	3,000
	31-50	2,400-2,600	2,800-3,000
	51+	2,200-2,400	2,400-2,800

* Moderately active means a lifestyle that includes physical activity equivalent to walking about 1.5 to 3 miles per day at 3 to 4 miles per hour, in addition to the light physical activity associated with typical day-to-day life.

** Active means a lifestyle that includes physical activity equivalent to walking more than 3 miles per day at 3 to 4 miles per hour, in addition to the light physical activity associated with typical day-to-day life.

***Children younger than 2 have rapidly increasing calorie requirements from 520 to 570 from 0-6 months to the estimated 1,200 at age 2-3. In this chapter the requirements of the 2-3 year olds was applied to children who were younger, but the increased calories required for pregnant and lactating mothers were not factored in to the older ages.

****Women who are pregnant have an increasing calorie requirement by trimester reaching 18% more than the non-pregnant woman of the same age. Lactating women have an estimated 17% increase in caloric requirements. Neither was taken into account in the calculations in this chapter.

*****Calorie requirements are specified for median American height and weight for that height to give a BMI of 21.5 for females and 22.5 for males.

Source: Institute of Medicine, Food and Nutrition Board, *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids*, National Academies Press, 2002 Washington, D.C. As reprinted by Health and Human Services/United States Department Dietary Guidelines for Americans, 2005. www.health.gov./dietary guidelines/ Table 3.

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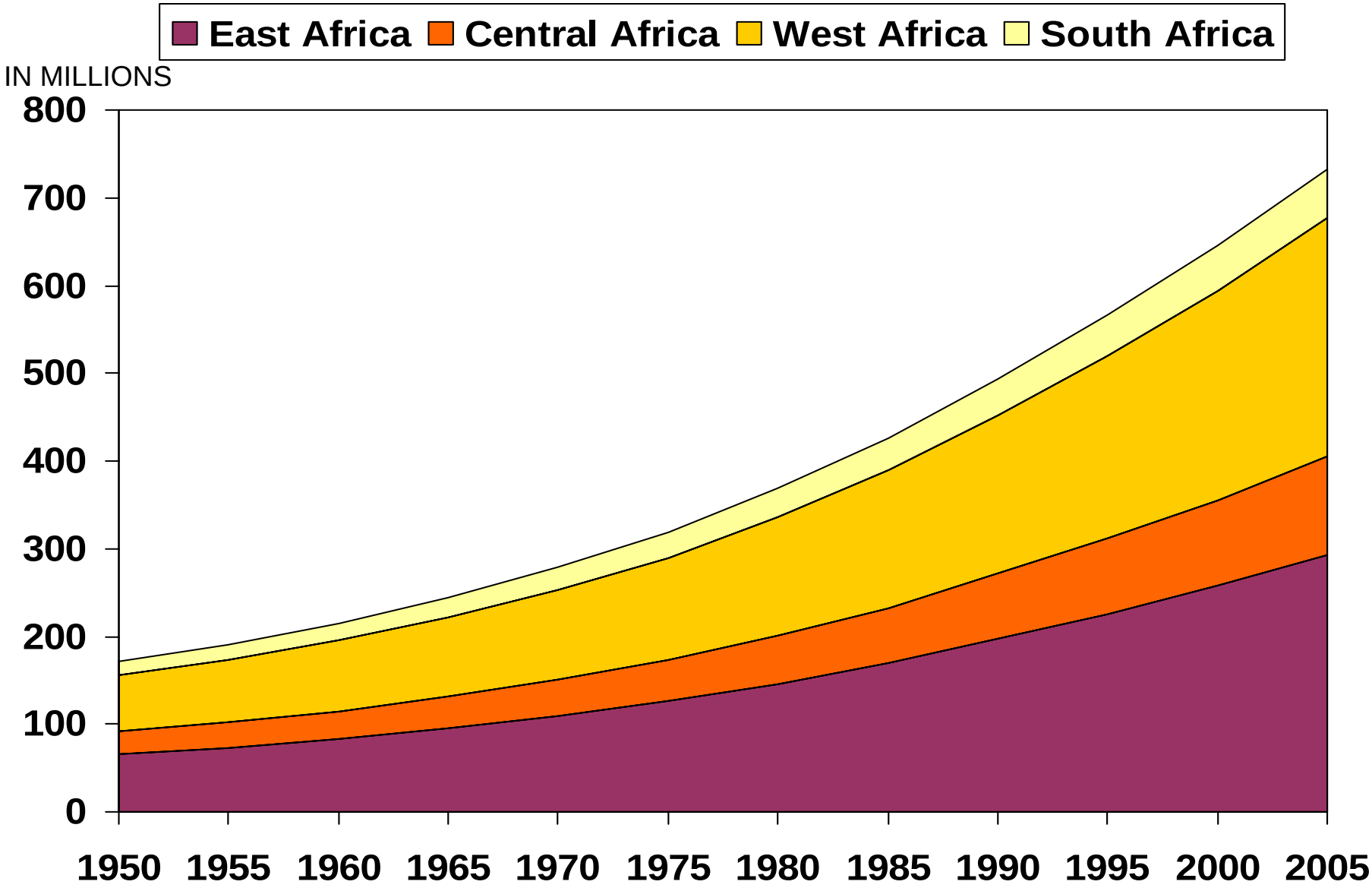
POPULATION PRESSURE, RESOURCE USE AND ENVIRONMENTAL DEGRADATION

POPULATION, AGRICULTURE AND ENVIRONMENT

IN SUB-SAHARAN AFRICA

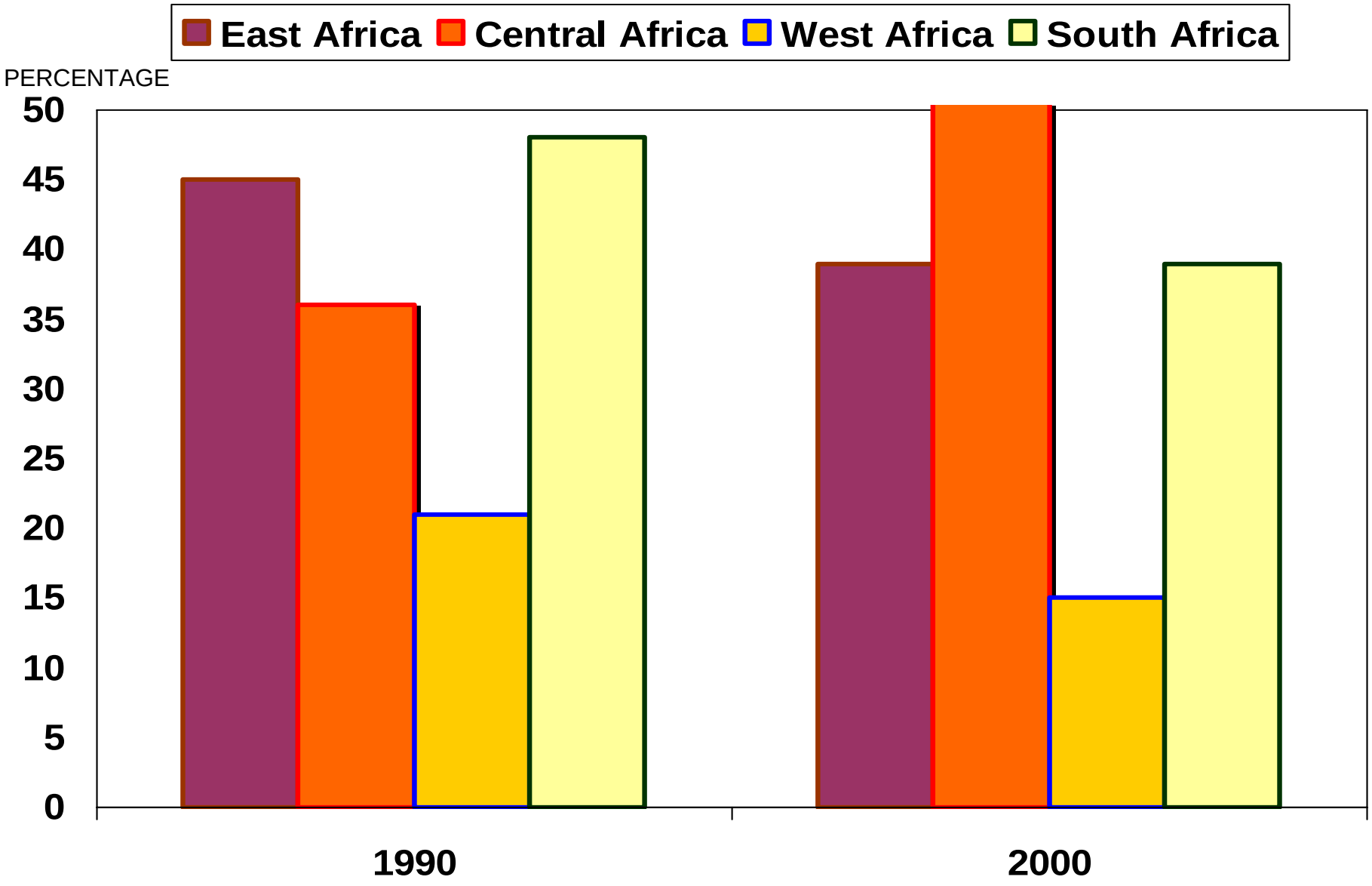
BARBARA BOYLE TORREY

CHART 1
POPULATION GROWTH IN AFRICA



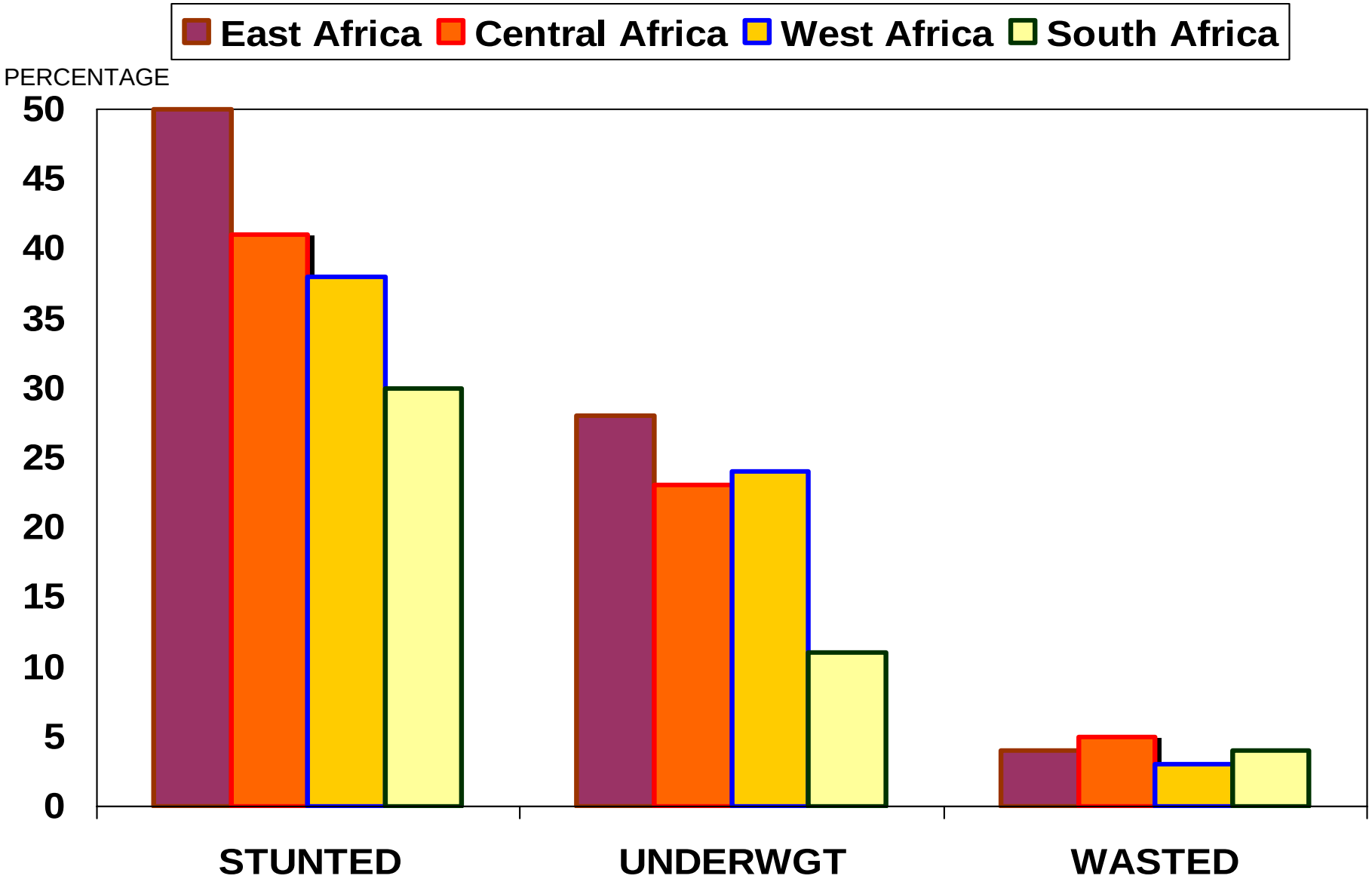
Source: United Nations, World Population Prospects: The 2006 Revision

CHART 2
UNDERNOURISHMENT IN TOTAL POPULATION



Source: The State of Food Insecurity in the World 2006, Table 1, p. 33. FAO Rome.

CHART 3
EVIDENCE OF CHILDHOOD UNDERNOURISHMENT 2005



Source: THE LANCET, Vol. 371,JAN. 19, 2008 p. 245. based on WHO Child Growth Standards.

ESTIMATED CALORIE REQUIREMENTS BY DEMOGRAPHIC CHARACTERISTICS

GENDER	AGE*****	MODERATELY ACTIVE*	ACTIVE**
CHILD***	2-3	1,000-1,400	1,000-1,400
FEMALE****	4-8	1,400-1,600	1,400-1,800
	9-13	1,600-2,000	1,800-2,200
	14-18	2,000	2,400
	19-30	2,000-2,200	2,400
	31-50	2,000	2,200
	51+	1,800	2,000-2,200
MALE	4-8	1,400-1,600	1,600-2,000
	9-13	1,800-2,200	2,000-2,600
	14-18	2,400-2,800	2,800-3,200
	19-30	2,600-2,800	3,000
	31-50	2,400-2,600	2,800-3,000
	51+	2,200-2,400	2,400-2,800

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Source: Institute of Medicine, Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids, National Academy Press 2002, Washington D.C.

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ETHIOPIA	1860	65.9	122.574

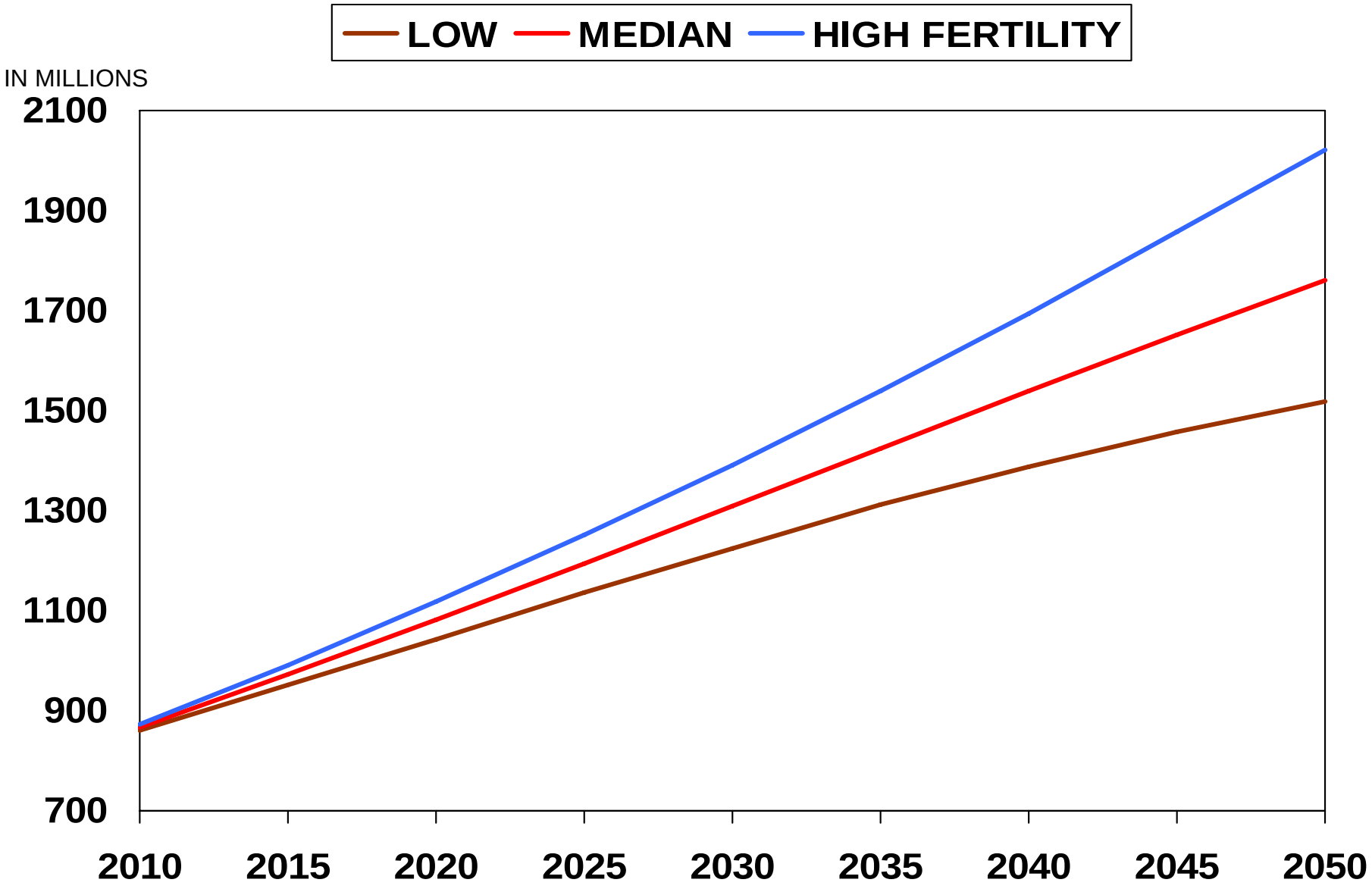
Sources: Dietary Energy Supply is from FAO Agricultural Produce 2001-2003
Pop estimates from PRB and the United Nations.

AVAILABLE CALORIES PER DAY (CONTINUED)

ZAMBIA	1930	9.8	18.914
ZIMBABWE	2010	11.4	22.914
TOTAL		643.8	1420.644

Sources: Dietary Energy Supply is from FAO Agricultural Produce 2001-2003. Population estimates from PRB and the United Nations.

CHART 5
FUTURE AFRICAN POPULATION



Source: United Nations, World Population Prospects: The 2006 Revision

DEMOGRAPHIC INFLUENCES ON CALORIC REQUIREMENTS

YEAR	TOTAL POP. (IN MILL)	URBAN POP. (IN MILL)	POP. 9+ (IN MILL)	TOTAL DAILY CAL REQUIRE. (IN BILL)
		MEDIUM POPULATION PROJECTIONS		
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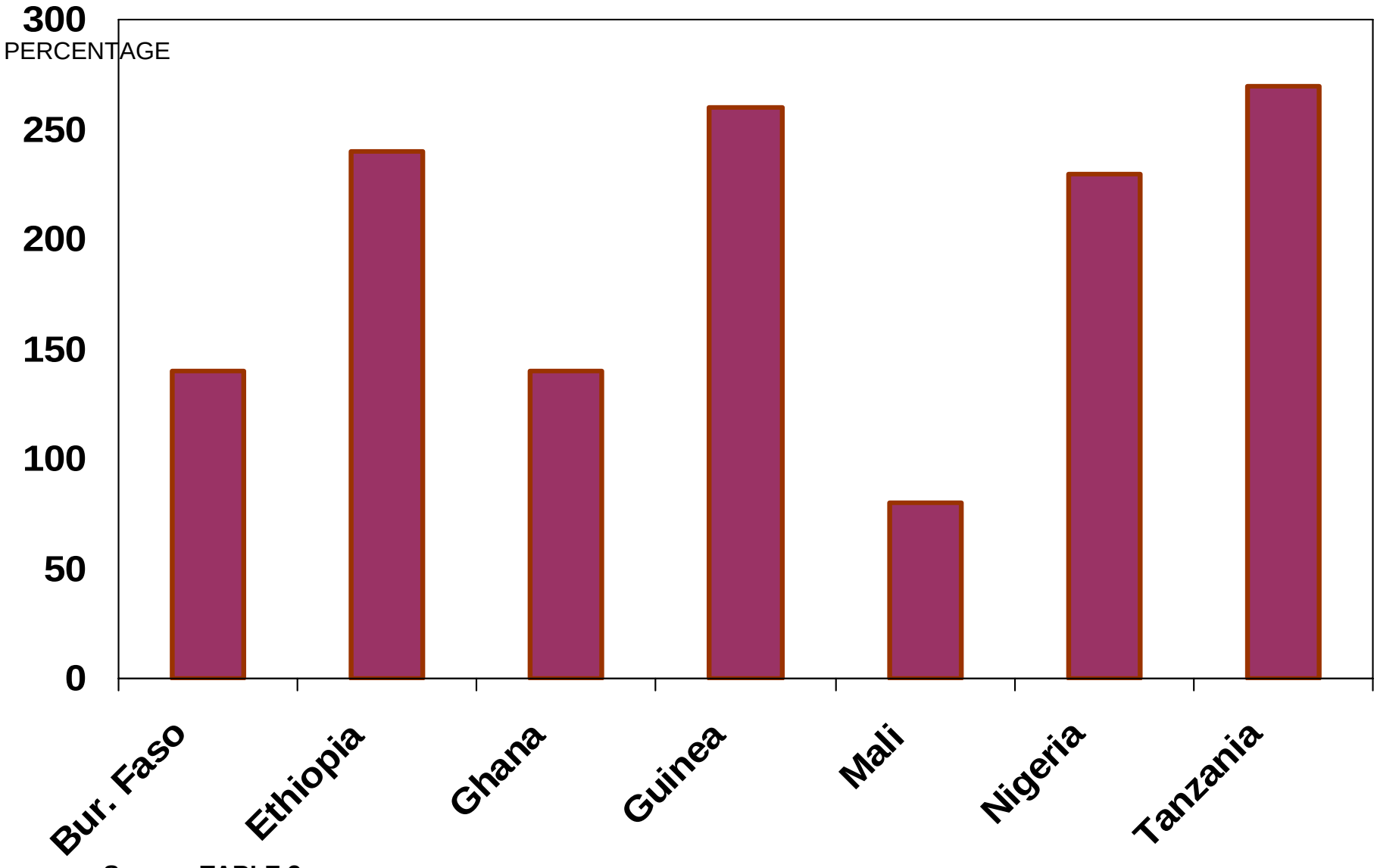
PERCENT INCREASE 2010-2050	103%	230%	134%	108%

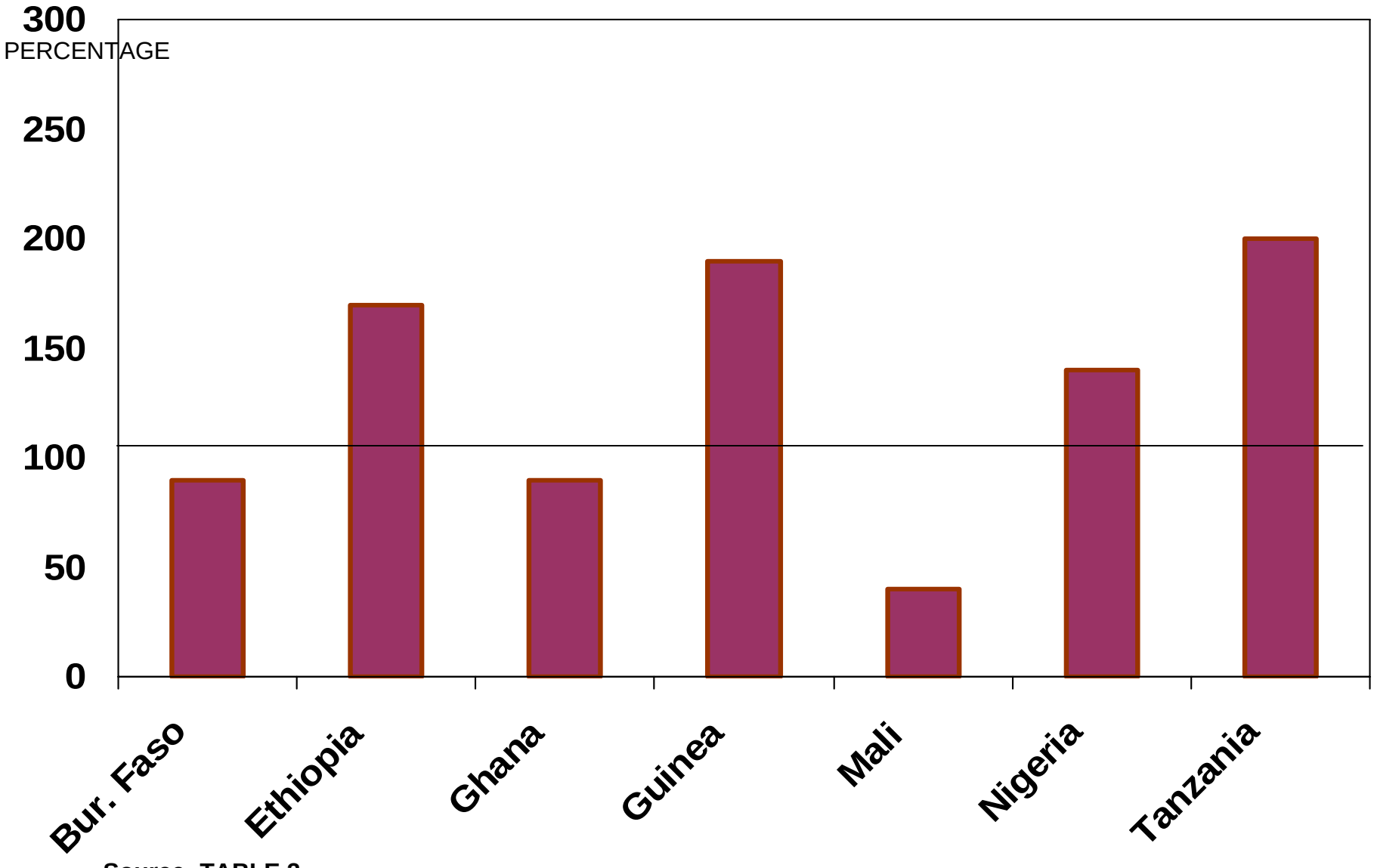
Source: UN World Population Prospects: The 2006 Revision and Institute of Medicine Dietary Reference Intakes, 2005.

CHART 6
INCREASE OF POTENTIAL CEREAL YIELDS OVER AVERAGE CURRENT YIELDS



Source: TABLE 3

CHART 7
INCREASE OF 80% OF POTENTIAL CEREAL YIELDS OVER AVERAGE CURRENT YIELDS



Source: TABLE 3