24 AUGUST 2012 No. 4

AFRICAN FUTURES BRIEF

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CULTIVATING THE FUTURE: EXPLORING THE POTENTIAL AND IMPACT OF A GREEN REVOLUTION IN AFRICA

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SUMMARY

Despite possessing large tracts of rich, uncultivated land, Africa is a net importer of food and suffers from high levels of undernutrition. Some scholars have argued that a 'Green Revolution', defined by increasing crop yields and land under cultivation, could bring about a more sustainable future for the continent. However, simply increasing yields and land under cultivation could lead to a world where buying steak in Europe is cheap while millions of Africans continue to go hungry or even starve. In this policy brief we explore the scope and impacts of policy choices that would increase yields and land under cultivation in Africa, and facilitate the regional consumption of food by those in need.

Using the International Futures (IFs) software to model alternative scenarios, we find that a massive increase in agricultural production is possible across the continent. With aggressive but reasonable policy interventions, Africa could become a net exporter of food in the next 10 years. However, a revolution in agricultural production, without developmental policy interventions, would lead to large quantities of food *leaving* the continent, resulting in increased consumption in rich countries while millions of Africans cannot access the calories they need. Promoting human development, therefore, requires coupling a green revolution with programmes to increase low-income consumption and access to food. In addition, production increases cannot be fully absorbed without improvements in water and sanitation as diarrheal diseases significantly diminish health improvements stemming from increases in caloric consumption. Many other uncertainties that cannot be dealt with here also remain, such as the impact of a green revolution on small-scale farmers and sustainable environmental practices.

AGRICULTURAL AND HUMAN DEVELOPMENT

Food is a vital part of human and social development. At the individual level, access to adequate, affordable and nutritious food is essential to health and wellbeing. Well-nourished individuals are more productive and can take advantage of educational and economic opportunities that will benefit themselves and society.

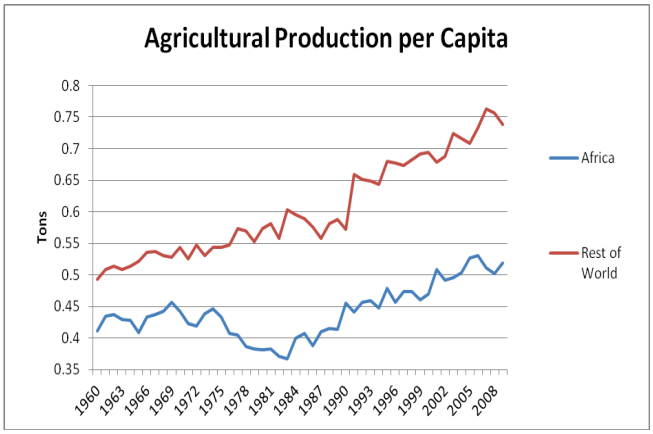
As defined by the World Health Organisation (WHO), food security exists 'when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life'.[1] Two characteristics of food security are availability (the amounts of food produced domestically and imported) and access (food prices and income levels). Food insecurity in Africa has led to 240 million people, 25 per cent of the continent's population, suffering from undernutrition.[2] The pandemic of undernourished people has been described as the 'equivalent to a disinvestment in human development'.[3]

Making more food available, and providing people with the resources to access it, would not only reduce un-

dernutrition but also catalyse development. Jean-Louis Arcand found that increasing per capita caloric consumption to 2 770 calories in countries below that threshold would increase GDP per capita growth by 0,53 per cent directly through health and productivity benefits, and 0,7 per cent indirectly through income effects.[4] In contrast, undernutrition can reduce GDP per capita growth by 0,2 to 4,7 per cent depending on its severity.[5] Using the IFs software, this brief models the effects of policies that lead to increased availability and access to food in Africa.

HISTORICAL TRENDS IN AGRICULTURE

From 1960 to 2010 Africa's total agricultural production tripled from 117 million to 357 million metric tons. This was the result of intensification (improvements in yield) and extension (expansion of area under cultivation). Average yields more than doubled from 0,9 tons per hectare to 1,9 tons per hectare and cropland grew by 61 per cent, or some 100 million hectares.[6] Despite this increase in output, growth in domestic food production per capita did not keep pace with that of the rest of the world, as indicated by the graph below.



Per capita caloric intake on the continent has only increased by 20 per cent over the past 50 years, from 2 048 calories per person in 1960 to 2 455 calories in 2010. Average caloric consumption in Africa is the second lowest of any global region (being slightly higher than that of South Asia) and remains well below the world average of 2 800 calories per person.[7] A notable year for the African food economy was 1981, when the continent moved from being a net exporter of agricultural produce to a net importer. This shift was highly significant for Africa in the sense that while caloric intake grew, the demand for food – particularly between 1981 to 2010 – was met through international imports and did therefore not benefit the continent's agricultural economy. Africa currently imports 45 per cent of its rice and 85 per cent of its wheat.[8] In monetary terms, agricultural imports have soared from US$ 13,8 billion[9] in 1981 (5,1 per cent of GDP) to US$ 114 billion (nearly 13 per cent of GDP) by 2010.[10]

Africa's inability to keep up with growth in global caloric consumption is not simply a product of poor soil or lack of land availability. In fact, the average maximum potential crop yield per country in Africa is nearly 8,5 tons per hectare, the highest of any region in the world.[11] Africa also has much additional land to use since only 20 per cent of its available arable land is currently under cultivation.[12] This is low in contrast to other regions; Asia uses over 77 per cent of its arable land, Europe over 45 per cent and North America over 46 per cent. The only regions using a lower percentage of available arable land are South and Central America, which use only 16 per cent.

Even though Africa's agricultural sector is underdeveloped, the continent's economy is highly dependent on it, more so than most world regions. Agriculture in Africa provides some 37 per cent of the continent's total GDP and employs 65 per cent of its workforce.[13] Therefore, aggressive and strategic improvement in this sector could directly benefit millions.

AGRICULTURAL DEVELOPMENT IN PRACTICE

As we look to the future, we should note some recent African success stories at country level that could serve as possible models. Two themes dominate these accounts: the effectiveness of increased agricultural research and extension, and strong policy support focused on a single crop. In the late 1970s and early 1980s, for example, massive mealy bug outbreaks destroyed cassava crops across much of Central Africa. By 1988 the mealy bug problem had largely been brought under control thanks to a US$ 15 million agricultural research programme employing biological pest control. The programme saved an estimated US$ 2,2 billion worth of cassava across the region.[14]

Cotton production in West Africa is another success story. In the 1960s, Mali, Côte d'Ivoire, Cameroon, the Central African Republic and Senegal established policies designed to support this sector. They guaranteed crop prices, established extension programmes to supply farmers with inputs to improve crop yields and guaranteed access to markets. As a result of these policies, cotton yields across the region increased from 0,22 tons per hectare in 1960 to 1 ton per hectare in 2006.[15] West Africa now supplies 14 per cent of the world's cotton.[16]

More recently, Malawi has successfully improved maize production. In 2005 production fell far short of domestic demand because of poor rainfall and over-used soil. The shortfall left five million people in need of food aid. In response, the Malawian government instituted an agricultural extension programme to provide improved seeds for the next season's planting, along with heavily subsidised fertiliser. In 2006, the maize harvest more than doubled from 1,2 million tons to 2,6 million tons, providing an 18 percent surplus. In 2007, maize production reached 3,4 million tons and Malawi became a food aid donor to neighbouring countries.[17]

These developments are positive indications that good agricultural policies can effectively lead to increased yields in Africa. However, a green revolution, entailing a massive increase in food production spurred by technological innovation, would require transformation on a much larger scale. Brazil and Vietnam are two cases where massive policy pushes in this area successfully reduced food insecurity, though with different impacts on small landholders and farmers.

The transformation of Brazil's agricultural sector is a development success story. Prior to its green revolution the Brazilian agricultural sector closely resembled that of some African countries. It relied heavily on labour-intensive methods and was largely oriented toward producing unprocessed commodities for export. And, like most African countries today, Brazil was a net food importer. But today Brazil is the world's largest exporter of coffee, sugar, ethanol, orange juice and poultry; the second largest producer of beef and soy beans; and the third largest producer of maize.[18] Brazil achieved this transformation by adopting policies in the 1960s and 1970s designed to increase soy bean production through more effective agricultural research and extension,[19] greatly increasing subsidised rural credit,[20] building new public infrastructure and converting large swathes of the Cerrado[21] to farmland.[22] The investments have paid off: 'In less than 30 years Brazil has turned itself from a food importer into one of the world's great breadbaskets'.[23]

However, the Brazilian agricultural revolution has not benefited all farmers. Most of the productivity gains and new farmland went to large agribusinesses. By 1996, Brazilian smallholder farms held 20 per cent of all farms but only 0,3 per cent of total farmland. Compare this with Ethiopia, where smallholder farms represented 87 per cent of all farms and 60 per cent of the farmland in 1999.[24]

Vietnam's green revolution was different from Brazil's as it placed the emphasis on the production of a single crop and promoted small-scale farms. The initial push for development started in the 1960s, but war prevented sectoral expansion for some time. Thereafter rice production grew massively at an average annual rate of five per cent from 1980 to 2000.[25] This rapid increase in production allowed Vietnam to go from near-famine conditions in the 1970s to being a major rice exporter by 1989 and the world's second-largest rice exporter today.[26]

As in the case of Brazil, agricultural research and extension in the form of high-yield rice strains and fertiliser subsidies played a major role in Vietnam's productivity gains. But equally, if not more important, were a series of land rights and market reforms in the 1980s and early 1990s designed to keep the smallholder farm as 'the main unit of agricultural production'.[27] This resulted in the bulk of agricultural production being retained in the country even as production of export-oriented crops like coffee, cashew nuts and livestock increased.[28] With 80 per cent of the country's population living in rural areas, this focus has helped reduce poverty rates. In 1993, 63 per cent of Vietnamese were living on less than US$ 1,25 per day (2005 dollars), but by 2008, only 11 per cent were.[29]

THE TOOL: INTERNATIONAL FUTURES

Given some of the issues and experiences discussed above, we have built alternative scenarios for African agricultural development using the International Futures (IFs) model.[30] IFs is an integrated assessment model that represents demographic, economic, energy, education, health, agriculture, infrastructure, socio-political and environment sub-models for 183 countries. The relationships within and across these sub-systems are quantitatively formalised within IFs to analyse trends and forecast alternative scenarios to 2100. The model is housed at the Frederick S Pardee Center for International Futures at the Josef Korbel School of International Studies, University of Denver, and is available for download or use online for free at www.ifs.du.edu/ifs. Our goal for this modelling project was to frame multiple uncertainties around decisions faced by policy makers. We analysed three scenarios for this purpose: the IFs Base Case, the African Green Revolution, and the African Green Revolution for Development.

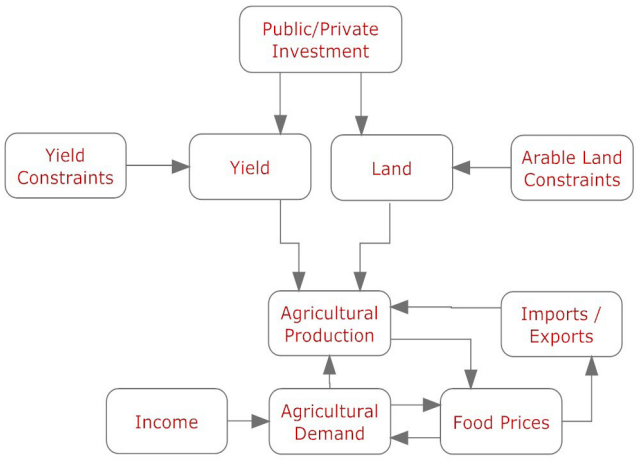
The IFs Base Case is a dynamic scenario that represents a continuation of technological improvement, policy investment choices and natural resource availability as they have evolved over the decades since the end of the Cold

War. It is a plausible scenario for global human development that does not contain any radical transformation, technological or otherwise, and is a reference point for establishing expectations about continuity and change within and across systems and countries. The Base Case is a generally optimistic scenario allowing for much improvement in human development occurring across Africa and other developing regions.[31]

The agricultural sub-model of IFs begins with two basic components: cropland and production. Cropland is represented using Food and Agricultural Organisation (FAO) data and changes endogenously with signals of world food prices guided by demand.[32] Production is driven directly by the average yield per hectare of land, the growth of which is capped using data taken from the Global Agro-ecological Zone (GAEZ) Assessment[33] and is reduced through food loss, represented conceptually as occurring both in the field and as wasted end-point consumption. The production of both crops and meat in the IFs model interacts with the demand for food. This takes two main forms: demand for crops and meat from end-point consumers, and demand for industrial production, e.g. the inputs for a brewery. Imports and exports of agricultural production follow historical patterns and are initialised using data from the FAOSTAT Trade Database, the FAO statistical data base.[34]

A highly simplified representation of our approach to modelling agriculture is shown in the diagram below. Each of the variables is endogenised within the broader IFs system, although those linkages are not shown in the diagram. Full documentation of model assumptions can be found on the IFs website or in the model's Help System.[35]

Major components of IFs agriculture model



MODELLING GREEN REVOLUTIONS

Food security in Africa is characterised by poor access (with very low calories available per capita) and questionable availability (with high levels of food imports). While the Base Case of the IFs forecasting system as described above is generally optimistic about development across the continent, food security remains a sector of concern. In terms of food access, only eight of the 52 African countries represented in the IFs model enjoy calories per capita higher than the global average in 2012, and only 17 countries show per capita calories above the global 2012 value by 2050. In terms of availability, only two of the 52 African countries represented in IFs are expected to be net exporters of crops in 2012, namely South Africa and Guinea Bissau.[36] Of these, only South Africa is forecast to remain a net exporter to 2050 in the Base Case.

To explore the impacts of policy variations, we ran two alternative scenarios in addition to the Base Case – one we named the African Green Revolution and the other is named the African Green Revolution for Human Development.

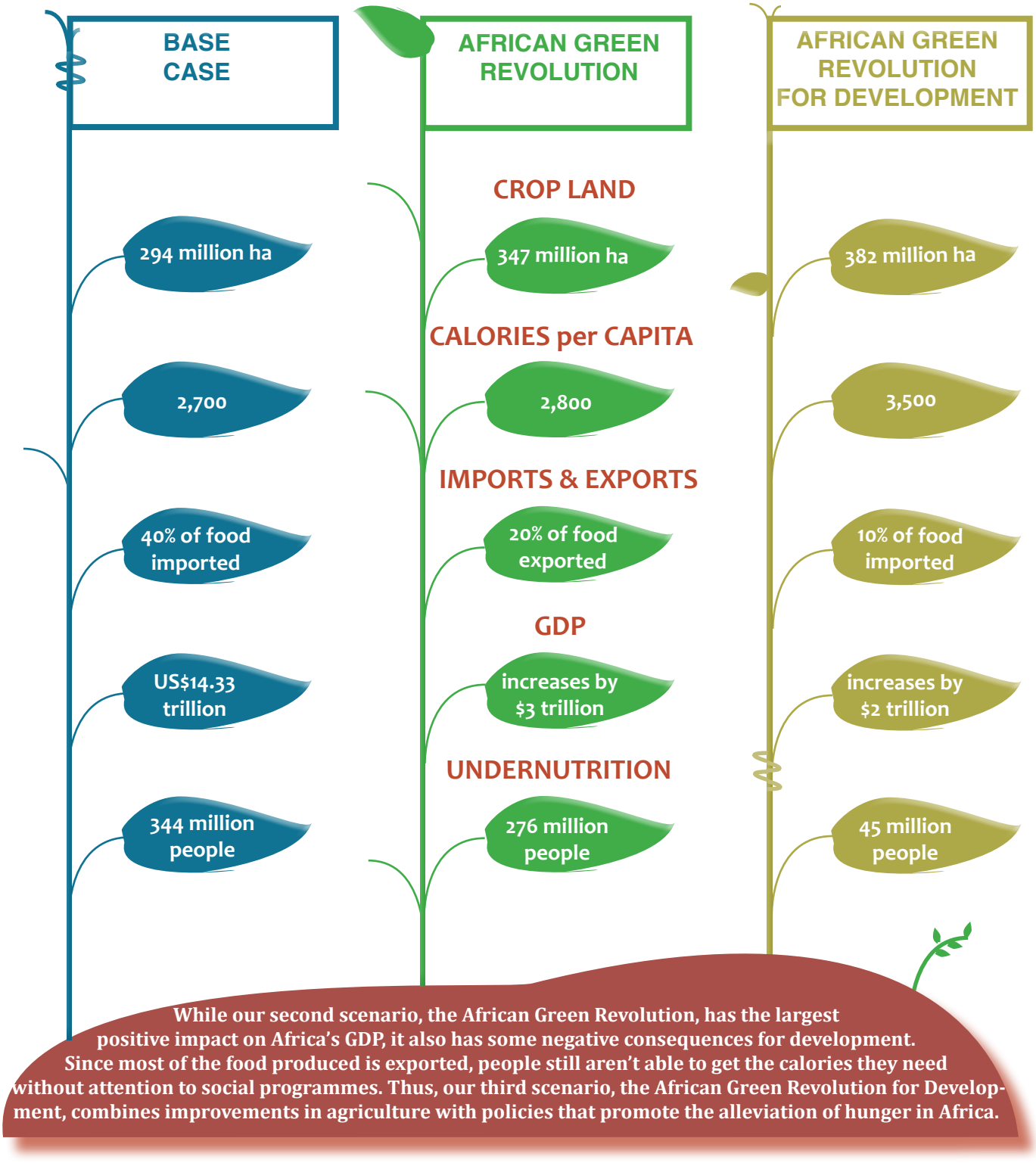
In the first scenario, the African Green Revolution, we increased agricultural output across the continent by introducing both private and public interventions.[38] We first increased private investment in agriculture by 10 per cent over Base Case values. This was not sufficient to significantly improve food security, in part because it led to less investment in other capital sectors such as services, manufacturing, materials, information and communications technology, and energy, and slightly reduced overall economic output.

We then augmented the private sector intervention by simulating a continent-wide public push to improve yields and increase the amount of land under cultivation. Growth in yields[38] and land placed under cultivation[39] were capped at levels identified by the FAO as reasonable upper limits.[40] The increases in both variables were generally in line with previous agricultural production revolutions to simulate a scenario that was both aggressive and reasonable.[41]

A comparison of the Base Case with the African Green Revolution scenario shows impressive results for both the public and private interventions. In the Base Case the amount of cropland used in Africa increases from around 260 million hectares to 300 million hectares by 2050. But the African Green Revolution scenario increases this by an additional 50 million hecatres, an area nearly the size

AFRICA'S BEST HARVEST

Lets find out how our scenarios stack up in 2050



While our second scenario, the African Green Revolution, has the largest positive impact on Africa's GDP, it also has some negative consequences for development. Since most of the food produced is exported, people still aren't able to get the calories they need without attention to social programmes. Thus, our third scenario, the African Green Revolution for Development, combines improvements in agriculture with policies that promote the alleviation of hunger in Africa.

of Botswana. Of the new land added, 20 per cent would come from deforestation. The IFs model includes the cost of converting marginal and forestland to cropland, impacting the economic sub-model. Turning to crop yield, in the Base Case average African crop yield increases from 1,9 tons per hectare to 2,9 tons per hectare over the four-decade horizon. This increase in yield is similar to the rate of increase experienced by Africa since 1960. Our aggressive production scenario expands yields more rapidly and to higher levels, increasing output to 4 tons per hectare by 2030.

We also compared the extent of reliance on food imports. In the Base Case, Africa imports about 12 per cent of the calories consumed in 2012. By 2050 we forecast this to increase to a staggering 40 per cent. The African Green Revolution scenario, on the other hand, forecasts Africa to become a net *exporter* of crops in 10 years, increasing to nearly 20 per cent of total production over four decades. Further, by 2050, 25 countries on the continent would be net exporters of crops in this scenario.

In absolute terms, the Base Case forecasts growth in agricultural output to nearly double over the next 40 years. However, the African Green Revolution scenario raises output from just over 500 million tons today to over 1 800 million tons by 2050, more than tripling production. In absolute terms, the greatest production increases would occur in Nigeria, Ethiopia and Uganda.

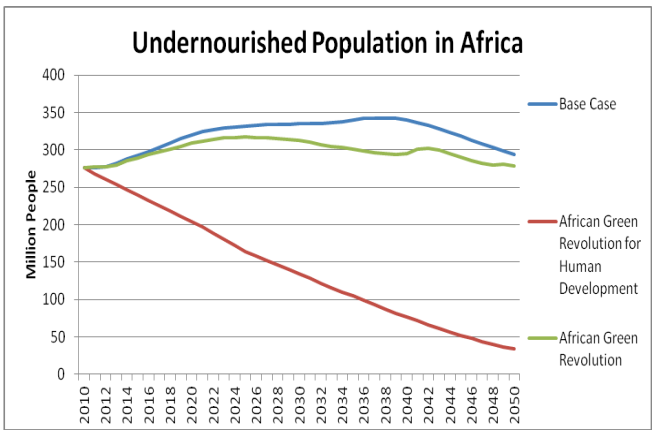
The forward impacts of this policy choice would cause economic production to grow as well. Compared with the Base Case, the overall African economy would be over US$ 3 trillion larger by 2050.[42] The greatest economic expansion relative to the Base Case would occur in Ghana, Uganda, Ethiopia, Morocco and South Africa, largely driven by massive increases in agricultural exports.

However, simply increasing private and public investment in the agricultural sector at aggressive but reasonable levels would not adequately drive human development. The African Green Revolution scenario would reduce the percentage of undernourished children by 2050 by less than 1 per cent compared with the Base Case. This small improvement can be ascribed to the fact that the greater part of the production increase would be exported to feed high-end consumption abroad. For example, by 2050 the global price of meat would be reduced by 20 per cent relative to the Base Case and meat consumption in the USA alone would increase by over 4 million tons. In summary, under the African Green Revolution scenario the developmental benefits of increased caloric intake would not accrue to Africa.

To improve food consumption among Africa's poor, and to put the food produced in a green revolution in African stomachs, the African Green Revolution must be coupled with programmes to increase food access and reduce the cost of food to consumers. This could be accomplished by means of a variety of public and non-governmental organisation (NGO) activities, such as vouchers, subsidies and direct transfers, and by keeping more small farmers on the land. We simulated these policies in our second alternate scenario, namely the African Green Revolution for Human Development scenario, by increasing overall domestic demand for food on top of the policy interventions explored in the African Green Revolution scenario.[43] The cost-benefit calculus changes substantially.

First, Africa would not become a net exporter of crops. Instead, most of the additional food would remain on the continent. Africa would continue to import food, but at much lower levels than in the Base Case, namely at around 10 per cent across the four-decade time horizon. Economically, the African Green Revolution for Human Development scenario increases GDP by over US$ 2 trillion compared to the Base Case – less than in the case of the African Green Revolution, but still a substantial improvement. Much of the economic growth seen in the agricultural production revolution derives from returns on trade of food in foreign markets. Economic growth in the African Green Revolution for Human Development scenario comes from improvements in human capabilities within Africa.

Such improvements result from improved health outcomes. In 2050, for example, compared with the Base Case, 11 million fewer children would experience undernutrition. The stunting rate, a measure of the long-term health impacts of undernutrition, would be reduced from 16 per cent in the Base Case to less than 10 per cent in the African Green Revolution for Human Development scenario. In total across the time horizon, there would be 650 million fewer years of life lost to disease, largely as a result of the increase in calories per capita to levels currently seen in rich countries. Total population undernutrition trends are shown in the line graph below for the three scenarios we explored.



In summary, simply increasing agricultural yields and land under cultivation is not sufficient to improve human development across Africa. That would require increased access to food on a wide scale, as captured in our African Green Revolution for Human development scenario, by simulating domestic demand for food in addition to increasing public and private investment. This bundle of policy choices could be augmented further by one other measure, namely an improvement of access to safe water and improved sanitation (see the first policy brief in this series, 'Taps and Toilets').[44] Providing additional calories does not lead to human development if serious diarrheal disease is prevalent.

There are several significant unexplored factors in this analysis. Further research should be conducted on the trade-offs between the promotion of large-scale agricultural production (as in Brazil) versus small-scale production (as in Vietnam). In addition, this brief does not look at the impact of large-scale agricultural growth on environmental sustainability and water use.

CONCLUSION

At face value, increasing agricultural production in Africa seems like a good idea. However, simply increasing yields and land under cultivation is likely to lead to a situation where developed countries can purchase food even more cheaply, while millions of Africans continue to go hungry or even starve. If Africa decides to promote agricultural production with effective plans for increasing yields and land under cultivation, the following additional questions must be answered to effectively promote human development:

- How do policymakers increase food distribution and demand stimulation across countries in Africa?
- Is the plan for agricultural stimulation focused on industrial agricultural production, small-scale production, or some combination of both? What are the socio-political implications of each focus?
- How might access to safe water and sanitation be improved most effectively so that the calories consumed are not wasted?

Africa has the capability and resources to produce a green revolution that promotes human development. However, that outcome is far from certain and relies on human decisions made today that will shape the world of tomorrow.

NOTES

[1] World Health Organisation, Food security, 2012. *Available at* http://www.who.int/trade/glossary/story028/ en/

[2] World Food Program (WFP), Who are the hungry? 2012. Available at http://www.wfp.org/hunger/who-are

[3] Xinshen Diao, Peter Hazell, Danielle Resnick and James Thurlow, The role of agriculture in development: implications for sub-Saharan Africa, International Food Policy Research Institute (IFPRI), Research Report 153 (2007), 9.

[4] Jean-Louis Arcand, Undernourishment and economic growth: the efficiency cost of hunger, UN Food and Agricultural Organisation (FAO), FAO Economic and Social Development Paper 147 (2001), 1.

[5] World Bank, World Development Report 2008: Agriculture for development, Washington DC, 95.

[6] Data from FAOSTAT and World Development Indicators (WDI), 2011.

[7] Calories per capita consumption data from FAOSTAT.

[8] Abigail Somma, The 10 per cent that could change Africa, IFPRI Forum, October 2008. Washington, DC: IFPRI 2008, 2.

[9] In 2005 dollars.

[10] Export data from WDI 2010.

[11] Data on crop yield from FAOSTAT. Regional averages were calculated using UN Population Division groupings.

[12] Data on arable land totals and percentage use from FAOSTAT.

[13] Jakkie Cilliers, Barry Hughes and Jonathan Moyer, African futures 2050 – the next forty years, Institute for Security Studies (ISS) and Pardee Center for International Futures, Pretoria, 7.

[14] Eleni Gabre-Madhin and Steven Haggblade, Successes in African agriculture: results of an expert survey, Washington, DC: IFPRI 2001, 18.

[15] This is still very low by world standards, but a marked improvement nonetheless.

[16] Eleni Gabre-Madhin and Steven Haggblade, Successes in African agriculture, 22.

[17] Pedro Sanchez and Glenn Denning, The African green revolution moves forward, Food Security 1 (2009), 37–44.

[18] Nicholas Rada, Steven Buccola and Keith Fuglie, Brazil's rising agricultural productivity and world competitiveness, Agricultural and Applied Economics Association (AAEA) & African Centre for Crop Improvement (ACCI) Joint Annual Meeting, Milwaukee, Wisconsin, 26–29 July 2009, 6.

[19] The Brazilian Agricultural Research Corporation (Embrapa) was founded in 1973 and is widely credited as the primary driver of the country's agricultural revolution through its work on developing new strains of soya beans and increasing the fertility of the Cerrado's soils.

[20] In 1976 agricultural credit reached a peak of 94 per cent of total agricultural GDP. Nicholas Rada, Steven Buccola and Keith Fuglie, Brazil's rising agricultural productivity, 4.

[21] The Cerrado is a tropical savannah eco-region that makes up 21 per cent of Brazil's territory. Carlos Klink and Ricardo Machado, Conservation of the Brazilian Cerrado, *Conservation Biology* 19(3), June 2005, 707–713; 1.

[22] Nicholas Rada, Steven Buccola and Keith Fuglie, Brazil's rising agricultural productivity. Also see Piaui Cremaq, Brazilian agriculture: the miracle of the Cerrado, *The Economist*, 26 August 2010.

[23] Piaui Cremaq, Brazilian agriculture.

[24] IFPRI, The future of small farms: proceedings of a research workshop, Wye, UK, 26–29 June 2005, Washington, DC: IFPRI, 363.

[25] Yields grew by 3,5 per cent and the harvested area by 1,5 per cent per year. Tran Thi Ut, The impact of green revolution on rice production in Vietnam, Workshop sponsored by the Foundation for Advanced Studies on International Development, Tokyo, 8–10 December 2002, 2.

[26] Pamela Whitby, The race for rice, BBC News Online, 8 February 2011.

Sally Marsh and Gordon MacAulay, Land reform and the development of commercial agriculture in Vietnam: policy and issues, Department of Agricultural Economics, University of Sydney, 2006, 1. See also Derek Bayerlee, Xinshen Diao and Chris Jackson, Agriculture, rural development and pro-poor growth: country experiences in the post-reform era, The World Bank, Agriculture and Rural Development Discussion Paper 21, 2005, 29.

[28] Sally Marsh and Gordon MacAulay, Land reform and the development of commercial agriculture in Vietnam, 2.

[29] Poverty headcount data from the WDI 2011.

[30] Further details on the model structure and assumptions are available on the IFs website. Version 6,58 of the model was used for the development of this report.

[31] Jakkie Cilliers, Barry Hughes, and Jonathan Moyer, African futures 2050, 7.

[32] FAOSTAT Resource Database 2012. Available at http://faostat.fao.org/ site/377/ default.aspx#ancor.

[33] Global Afro-ecological Zone Assessment, 2000. Available at http://www.iiasa.ac.at/Research/LUC/GAEZ/ index.htm.

[34] FAOSTAT Trade Database, 2012. Available at http://faostat.fao.org/site/ 342/ default.aspx.

[35] The online version can be found at http://www.ifs.du.edu/ifs/index.aspx. For detailed information about the structure of the model, please refer to Barry Hughes and Mohammod Irfan, The structure of international futures, 2004. Available at http://www.ifs.du.edu/assets/documents/ StructureofIFsV1_0.pdf.

[36] The IFs does not currently represent the Seychelles, South Sudan or Western Sahara.

[37] This project focused solely on increasing crop production, not meat production or the industrial consumption of crops. Both meat production and industrial consumption were impacted by crop production, as increases in crop production changes the cost of inputs to both meat and industrial production.

[38] An annual yield growth rate of 3,2 per cent was estimated to be appropriate for green-revolution conditions by analysing the historic yield growth rates of Brazil, India, China and Vietnam.

[39] The Guinea Savannah Zone (Nigeria, Mozambique and Zambia) includes almost 400 million ha of arable land, just 10 per cent of which is currently cultivated. Comparable to the Brazilian Cerrado, this area holds great potential for African agricultural development. World Bank, Awakening Africa's sleeping giant: prospects for commercial agriculture in the Guinea Savannah Zone, June 2009.

[40] Using data obtained from the Global Agro-ecological Zone Assessment, which identifies reasonable upper limits to agricultural yields globally and the FAO TERRASTAT Database (available at http://www.iiasa.ac.at/ Research/LUC/GAEZ/index.htm and http://www.fao.org/nr/aboutnr/nrl/en/ respectively.

[41] We also explored the idea of increasing government spending on agriculture to levels based on a monitoring and evaluation report by the Comprehensive African Agriculture Development Program (CAADP), which calls for African governments to commit 10 percent of their budgets to agricultural spending. The monitoring and evaluation report breaks down countries across Africa by current spending levels of greater than 10 per cent, five to 10 per cent and less than five per cent. For the scenario, countries were grouped based on this breakdown and their agricultural spending increased to 10 per cent as needed. We did not use this in our final modeling approach.

[42] By taking the cumulative difference across all years between the agricultural production revolution and the Base Case using a discount rate of three per cent.

[43] We increased overall agricultural demand by 40 per cent over a 15-year period starting in 2012.

[44] Mark Eshbaugh, Eric Firnhaber, Patrick McLennan, Jonathan D Moyer and Erin Torkelson, Taps and toilets, *African Futures Policy Brief* 1 (2011), 1–8.

AFRICAN FUTURES PROJECT

The African Futures Project (www.issafrica.org/futures) is a collaboration between the Institute for Security Studies (www.issafrica.org) and the Frederick S Pardee Center for International Futures (www.ifs.du.edu) at the Josef Korbel School of International Studies at the University of Denver. The Institute for Security Studies is a widely recognised Pan-African think tank specialising in issues of human security. The Pardee Center is the home of the International Futures modelling system, which is an integrated approach to exploring and understanding human development and the broad implications of policy choices. These organisations leverage each other's expertise to provide forward-looking, policy-relevant material that frames uncertainty around human development in Africa.

The authors would like to thank Eli Margolese - Malin for contributing to the literature review and editing of this policy brief and Natashia Emmett for layout and graphics design

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Project funding thanks to:
The Hanns Seidel Foundation, Government of Canada, Department of Foreign Affairs and International Trade; Frederick S. Pardee; the governments of Denmark, Finland, Germany, the Netherlands, Norway, Spain, Sweden and Switzerland; and the Open Society Foundation