Investments in agricultural yield increase in Africa

Mark W. Rosegrant, IFPRI, Washington DC

Shahnila Dunston, CSIRO, Queensland

Daniel Mason D'Croz, CSIRO, Queensland

Timothy B. Sulser, IFPRI, Washington DC

Keith Wiebe, IFPRI, Washington DC

Dirk Willenbockel, University of Sussex

Introduction

The population of Africa is projected to increase by more than 50% between 2010 and 2030, from 1.03 billion persons to 1.54 billion (Mason D'Croz et al. 2019). This rapid population growth together with strong income growth in Africa will result in big increases in food demand, putting strong pressure on food production. Food production growth also faces challenges from climate change, with higher temperatures and changing precipitation patterns as well as likely increased weather variability. With limited scope for expansion of crop and pastureland, increased agricultural productivity growth will be required to meet growing food demand, boost incomes, and reduce hunger.

As noted in Mason-D'Croz et al. (2019), since the 1960s, increasing agricultural productivity has been critical for reducing poverty and hunger globally (Pingali 2012; Dercon & Gollin, 2014; McArthur, 2015). However, Africa has benefited less than other regions from past investments and continues to have low agricultural productivity by global standards (GYGWPA, 2017). It is therefore important to understand the potential for alternative agricultural and rural sector investments to meet the challenges to food production growth in Africa through higher productivity, and to evaluate the economic returns to these investments. This note estimates the benefit-cost ratios of alternative investments to increase food production and reduce hunger.

Methodology

IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) is utilized here to explore the impacts of alternative agricultural investment scenarios on agricultural yield and production and hunger in Africa. The IMPACT modeling system allows analysis of socioeconomic and climate pathways with different assumptions about policy, agricultural research and development (R&D) investments, and investments in rural infrastructure and irrigation and water management. IFPRI's IMPACT model is an integrated modeling system that links information from climate models (Earth System Models), crop simulation models (for example, Decision Support System for Agrotechnology Transfer), and river basin level hydrological and water supply and demand models linked to a core global, partial equilibrium, multimarket model focused on the agriculture sector and a global general equilibrium model, GLOBE (see Robinson et al. 2015 for a detailed description of IMPACT). The linkage with the GLOBE model enables the assessment of the economy-wide impacts of climate change and agricultural investments, including gross domestic product (GDP) and per capita income, which are essential for determining the rate of return to investments.

The IMPACT and GLOBE model baseline scenarios are calibrated with respect to agricultural productivity, GDP, prices and economy-wide GDP. To accomplish this calibration, IMPACT variables including GDP growth, population growth, agricultural land supply and endogenous agricultural price projections from IMPACT are aggregated to match with the regional and sectoral aggregation structure of the GLOBE model. Once the models are calibrated, to assess the economy-wide general equilibrium economy-wide effects from any given IMPACT scenario, and to evaluate the resulting aggregate income and welfare effects, the agricultural productivity changes simulated in IMPACT are translated into corresponding productivity changes at the GLOBE region and activity level and are then replicated in GLOBE.

For example, climate shocks on agricultural productivity and prices simulated in IMPACT scenarios are transmitted from IMPACT to GLOBE, and GLOBE then simulates the impact on the rest of the economy. An additional iteration is then done to transmit the economy-wide effects on GDP back to IMPACT, so that the income effects on food demand are also captured. The same procedure is followed for investment scenarios (Willenbockel et al. 2018).

Scenario Specifications

For the application in this note, the linked IMPACT and GLOBE models are used to simulate projected agricultural outcomes under a reference scenario that includes baseline agricultural productivity growth together with climate and economic scenarios drawn from work developed for IPCC's fifth assessment report. These scenarios are defined by two major components. First, Shared Socioeconomic Pathways (SSPs) are global pathways that represent alternative futures for economic and population growth (O'Neill et al. 2014; O'Neill et al. 2015). Population growth and GDP growth are drawn from SSP2, which is a middle-of-the-road scenario that follows historical trends on economic and demographic growth. The SSP2 rates of population and initial GDP growth are maintained as the exogenous rates for the alternative investment scenarios. The changes in GDP growth under the different scenarios are made endogenous to the specified scenarios through the linkage to GLOBE that is described above.

The second component is the Representative Concentration Pathways (RCPs), which represent potential greenhouse gas emission levels in the atmosphere and the subsequent increase in solar energy that would be absorbed (radiative forcing). There are four RCPs, which are named according to the approximate level of radiative forcing in 2100, which ranges from 2.6 watts per square meter (W/m^2) to 8.5 W/m^2. RCP8.5, which is the strongest climate change scenario, is utilized here as the climate change scenario. In 2030 the differences between these four RCPs are very small in carbon dioxide equivalent concentrations and radiative forcing (Mason-D'Croz, et al. 2019, Figure 2). Major divergences across the RCPs occur after 2030.

Following establishment of the reference scenario, two investment scenarios are run. First, a comprehensive investment scenario (COMP) is simulated for agriculture and the rural sector, which combines increased investments in agricultural R&D, irrigation expansion, water use efficiency, soil and water management, and rural infrastructure in developing countries. Rural infrastructure includes rural roads, rail, and rural electrification. These investments generate economic benefits through several pathways. Increased agricultural R&D boosts crop and livestock yields, reduces food prices, and increases farm income and economy-wide GDP through multiplier effects on the non-agricultural sectors. Irrigation and water use efficiency investments increase crop yields and reduce prices, thereby generating higher incomes. Enhanced rural infrastructure reduces post-harvest losses and marketing margins, improving the profitability of farm production, and boosting supply to consumers for any given level of production. These effects also increase farm and broader income. The COMP scenario is described in more detail in Mason-D'Croz et al. (2019), which also provides the key underlying results required for the computation of economic returns to investment.

Second, the impact of agricultural R&D is assessed separately in a scenario that simulates increased investment in international agricultural R&D (the HIGH scenario), which is described in detail in Rosegrant et al. (2017). This HIGH agricultural R&D scenario here is specified as increases in expenditures on crop and livestock breeding and supporting activities in the International Agricultural Research Centers of the Consultative Group on International Agricultural Research (CGIAR) in Africa. In addition to public expenditures on agricultural R&D, private sector investment in agricultural R&D plays an important role in agricultural productivity growth. In much of the world, private sector investment in agricultural R&D has increased faster than public sector investment, but private sector investment in agricultural R&D remains low in Africa and other low-income regions. Whereas private firms in rich countries spent $1.10 for every dollar of public agricultural R&D in 2011, private investment in low income countries was only $0.15 for every dollar of public investment in agricultural R&D (Pardey et al. 2016a). Projected growth in private sector investment in agricultural R&D reflecting recent growth trends is included in the reference scenario. Alternative scenarios for private sector investment in agricultural R&D are not simulated here, since the focus of this report is on public investments.

Among the results generated by these simulations are the projected per capita income for Africa in 2030 under the reference scenario and the COMP and HIGH scenario. Through the utilization of the GLOBE CGE model, the net economic benefits represented by per capita income, account for changes in costs and returns to inputs not only in the agricultural sector, but also income effects in the broader economy that are induced by the increased productivity growth due to agricultural research and development. In the model, producers in each sector and region combine primary factors (that is skilled and unskilled labor, physical capital, land and other natural resources) and intermediate inputs obtained from the same and other production sectors at home and abroad to produce outputs. The production process generates factor income in the form of wages, other in-kind returns to labor, land and natural resource rents and returns to capital as well as producing tax income for the government (Willenbockel et al. 2018). These results are then utilized to compute the net present value (NPV) of the stream of income benefits, 2015-2030. The benefit-cost ratio of additional agricultural investments is then computed as the ratio of the NPV of benefits to the NPV of the stream of additional investment costs.

Results

The COMP investment portfolio has a total annual additional cost for all developing countries to be about $52 billion per year from 2015 to 2030 (Mason-D'Croz et al. (2019), Table 5). The total annual investment cost for Africa and West Asia is almost $15 billion per year, or 29 percent of total investment across all developing countries (Mason-D'Croz et al. (2019), Table 5).

The stream of additional investments is shown in Table 1 here. The per capita GDP benefits of the additional investments are projected to be $228 per capita GDP in 2030 compared to the reference scenario (Mason-D'Croz et al. (2019), data underlying Table 6). The increase in total GDP is $350 billion in 2030 compared to the reference scenario, computed by multiplying the gain in per capita GDP in 2030 by the projected population in 2030. The annual stream of GDP benefits between 2015 and 2030 is computed as proportional to the cumulative increase in investments and is shown in Table 1. The NPV of incremental investment costs at a 5% discount rate is $171 billion and the NPV of income benefits is $1,747 billion. The benefit-cost ratio is therefore 10:1, showing high economic returns to investment in agriculture and rural infrastructure.

The HIGH agricultural R&D scenario has a much higher benefit-cost ratio. The average annual incremental investment in international agricultural R&D of the HIGH scenario is $0.67 billion per year from 2015 to 2030 (Mason-D'Croz et al. (2019), Table 5), which is double the average investment in the reference scenario (Mason-D'Croz et al. (2019), Table 4). The GDP benefits of the additional investment in R&D are projected to be $69 per capita GDP in 2030 compared to the reference scenario (calculated from Rosegrant et al. 2017). Following the procedure described above, the increase in total GDP is $106 billion in 2030 compared to the reference scenario, computed by multiplying the gain in per capita GDP in 2030 by the projected population in 2030. The annual stream of GDP benefits between 2015 and 2030 is computed as proportional to the cumulative increase in investments and is shown in Table 2. The NPV of incremental investment costs at a 5% discount rate is $5.6 billion and the NPV of income benefits is $290 billion. The benefit-cost ratio is therefore 52:1. Investments in agricultural R&D have very high rates of economic returns in Africa. This result can be compared to the findings in Pardey et al. (2016b), which reviews existing studies of economic returns to agricultural R&D between 1975 to 2014. The review included 129 benefit-cost ratios (BCRs), which averaged 30:1. However the comparison of these BCR results is not fully comparable, since the discount rates used in these BCR computations reviewed in Pardey et al. (2014) are not provided. The high BCR estimates here, and in the literature, indicate that investments in agricultural R&D in Africa are far too low.

Hunger-Calorie Pathway

Schofield (2014) finds that an increase in per capita calorie consumption by 700 calories per person in a low-calorie population results in an increase in income by 10%. The COMP scenario results in an average national increase of 250 calorie per person in 2030 (Mason-D'Croz et al. 2019, Figure 8). Assuming that the 220 million persons classified as hungry in 2010 achieve the same average increase in calorie consumption, per capita income of hungry people will increase by 3.6% (250/700 times the 10% increase in per capita income from Schofield (2014)). Next, assume that the per capita income of hungry people is one-half of the national average in the reference scenario, or $2,550 per capita in 2030. The increase in per capita total income for this cohort is then $91 (3.6% times $2,550) in 2030. Multiplied by the 220 million hungry people who achieve this gain, the increase in total income amounts to $20 billion in 2030. The annual stream of GDP benefits between 2015 and 2030 is computed as proportional to the cumulative increase in investments, at a 5% discount rate and at a 0% discount rate. The benefit-cost ratios for these hunger-calorie benefits cannot be estimated separately from the yield-income benefits computed above, because they are joint outcomes of the COMP investment scenario.

Adding the two streams of benefits generates a benefit-cost ratio of 10.8:1 if the hunger-calorie benefits are discounted at 5%, and 11.1:1 if these benefits have a 0% discount rate.

The HIGH scenario results in an increase in annual calorie consumption of 88 calories per capita in 2030, as calculated from Rosegrant et al. (2017). Following the method described above for COMP, the increase in total income in 2030 is $7 billion. The benefit-cost ratios of the combined yield-income and hunger-calorie benefits under HIGH are 55:1 with the hunger-calorie benefits discounted at 5% and 58:1 with these benefits discounted at 0%.

Conclusions

Broad-based investments in agricultural R&D and rural infrastructure generate very large total economic benefits and big reductions in hunger in Africa. Because of the high cost of physical infrastructure such as roads, electricity, and irrigation, the BCR of a comprehensive package of these investments is lower than for increased investments in agricultural R&D, although it still has a substantial BCR of 10:1. Given the high impacts on economic growth, these investments warrant serious consideration as necessary complements to agricultural R&D and targeted investments in hunger and nutrition programs. As a stand-alone investment program, increased spending on international agricultural R&D has a very high BCR of 52:1. This result indicates severe underinvestment in agricultural R&D in Africa and the need to substantially increase such investment. The International Agricultural Research Centers of the CGIAR are well-placed to scale-up agricultural R&D investments in Africa, with research facilities and programs in place in many country and regional programs across Africa. A phased doubling of investments between 2015 and 2030 is highly feasible. As with any increase in investments, there are risks, including the rate of success of generating well-adapted new technologies, and the rate of adoption of these technologies. To address these risks and achieve the large potential benefits of increased investment in agricultural R&D (and rural infrastructure), key stakeholders, such as governments, non–government organizations, international donor agencies, and the private sector should be involved. And, as with all interventions, enabling conditions should be improved, including access to credit and risk insurance, extension services, and complementary inputs.

References

Dercon, S., and Gollin, D. (2014). Agriculture in African Development: Theories and Strategies. *Annual Review of Resource Economics*, 6(1): 471-492. doi: 10.1146/annurev-resource-100913-012706

GYGWPA (2017). *Global Yield Gap and Water Productivity Atlas.* Available at: www.yieldgap.org. Accessed on: 2/5/2017

Mason-D'Croz, D., Sulser, T. B., Wiebe, K., Rosegrant, M. W., Lowder, S. K., Nin-Pratt, A., Willenbockel, D., Robinson, S., Zhu, T., Cenacchi, N., Dunston, S., and Robertson, R. D. (2019). *World Development*, *116*, 38–53. https://doi.org/10.1016/j.worlddev.2018.12.006

McArthur, J.W. (2015). Agriculture's Role in Ending Extreme Poverty. Chapter 6 in Chandy, L., Kato, H., & Kharas, H (Eds.) *The last mile in ending extreme poverty.* Washington, DC: Brookings Institution Press

Pardey, P.G., C. Chan-Kang, S.P. Dehmer, and J.M. Beddow (2016a). Agricultural R&D is on the move. *Nature* 537(7620): 301-303. https://doi.org/10.1038/537301a

Pardey, P.G., R.S. Andrade, T.M. Hurley, X. Rao, and F.G. Liebenberg (2016b), Returns to food and agricultural R&D investments in Sub-Saharan Africa, 1975–2014. *Food Policy* 65: 1-8. https://doi.org/10.1016/j.foodpol.2016.09.009;http://www.sciencedirect.com/science/article/pii/S0306919216303761

Pingali, P. (2012). Green Revolution: Impacts, limits, and the path ahead. *Proceedings of the National Academy of Science,* 109(31): 12302–12308. doi: 10.1073/pnas.0912953109

Robinson, S., Mason-D'Croz, D., Islam, S., Sulser, T., D. Robertson, R., Zhu, T., Gueneau, A., Pitois, G., and Rosegrant, M. W. (2015). *The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model description for version 3*. IFPRI Discussion Paper 1483. Washington, D.C.: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/129825

Rosegrant, M.W., Sulser, T.B., Mason-D'Croz, D., Cenacchi, N., Nin-Pratt, A., Dunston, S., Zhu, T., Ringler, C., Wiebe, K., Robinson, S., Willenbockel, D., Xie, H., Kwon, H-Y., Johnson, T., Thomas, T.S., Wimmer, F., Schaldach, R., Nelson, G.C., and Willaarts, B. (2017). *Quantitative Foresight Modeling to Inform the CGIAR Research Portfolio*. Project Report, Washington DC, USA: International Food Policy Research Institute (IFPRI).

Schofield, H. (2014). The Economic Costs of Low Caloric Intake: Evidence from India. http://ices.gmu.edu/wp-content/uploads/2016/03/The-Economic-Costs-of-Low-Caloric-Intake-Evidence-from-India-by-Schofield.pdf

Willenbockel, D., Robinson, S., Mason-D'Croz, D., Rosegrant, M.W., Sulser, T.B., Dunston, S., and Cenacchi, N. (2018) Dynamic Computable General Equilibrium Simulations in Support of Quantitative Foresight Modeling to Inform the CGIAR Research Portfolio: Linking the IMPACT and GLOBE Models. IFPRI Discussion Paper 01738. Washington, DC.: International Food Policy Research Institute (IFPRI). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/132757

Table 1. Annual investment costs and economic benefits of comprehensive investment (COMP) in agriculture and infrastructure in Africa, 2015-30, US$ billion.

Year	Costs	Benefits
2015	27.7	10.9
2016	58.7	34.1
2017	58.8	57.2
2018	58.9	80.5
2019	58.9	103.7
2020	59.0	126.9
2021	59.1	150.2
2022	59.2	173.6
2023	59.3	197.0
2024	59.4	220.4
2025	59.5	243.8
2026	59.6	267.3
2027	59.8	290.9
2028	59.9	314.5
2029	60.0	338.2
2030	32.5	351.0

Table 2. Annual investment costs and economic benefits of increased investment in agricultural R&D in Africa, 2015-30, US$ billion.

Year	Costs	Benefits
2015	0	0
2016	0.05	0.5
2017	0.1	1.6
2018	0.16	3.3
2019	0.23	5.8
2020	0.31	9.1
2021	0.4	13.4
2022	0.49	18.6
2023	0.59	25.0
2024	0.7	32.5
2025	0.82	41.3
2026	0.94	51.3
2027	1.07	62.8
2028	1.2	75.7
2029	1.34	90.0
2030	1.49	106.0