Consilience

SCHOLARLY ARTICLE

# The African Millennium Villages

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**Abstract:**

We describe the concept, strategy and initial results of the Millennium Villages Project (MVP) and implications regarding sustainability and scalability. Our underlying hypothesis is that the interacting crises of agriculture, health, and infrastructure in rural Africa can be overcome through targeted public-sector investments to raise rural productivity, and thereby to increased private-sector saving and investments. This is carried out by empowering impoverished communities with science-based interventions. 78 Millennium Villages have been initiated in 12 sites in 10 African countries, each representing a major agroecological zone In early results, the research villages in Kenya, Ethiopia and Malawi have reduced malaria prevalence, met caloric requirements, generated crop surpluses, enabled school feeding programs, and provided cash earnings for farm families.

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**Introduction:**

At the Millennium Summit in September 2000, world leaders set forth quantified and time bound goals---the Millennium Development Goals (MDGs)---to cut extreme poverty, hunger, disease, gender inequality, environmental degradation, and lack of access to safe drinking water and sanitation. In January 2005 the UN Millennium Project released a series of reports identifying practical ways to achieve the MDGs[2]. While the MDGs have been generally accepted as the world's goals, there are questions and controversies about how to attain them. Sub-Saharan Africa is the only region still severely off-track to reach the MDGs by 2015[2]. Several biophysical and economic constraints impede sub-Saharan Africa's escape from extreme poverty including extremely low productivity of food production[3], heavy burden of infectious disease[4,5], and insufficient core infrastructure in water, roads, power and telecommunications[6,7].

**Rationale:**

The poverty trap in Africa results from the extreme shortage of productive capital in the rural areas where over 70% of the population lives. A sub-subsistence living standard means that survival is dependent on low or zero financial saving, and the depletion of natural capital, a form of dis-saving. Poverty prohibits African households from self-financing farm inputs on the open market, and the lack of collateral and high transactions costs prohibit the finance of inputs through market-based credits. Risk of drought add to the barrier of market-based financing of the poor. The result is that a high proportion of households plant their crops without improved inputs (seeds, fertilizers), and soils become depleted of nutrients after repeated crop cycles without sufficient nutrient replenishment[7]. There is little scope for net positive saving or environmental sustainability.

Just as Africa's food crisis is a reflection of the interaction of biophysical and economic factors, so too is the health crisis. Disease burdens reflect an interaction of tropical climates, disease vectors unique to Africa, and the lack of basic public health services [1, 3, 4]. Malaria and AIDS stand out as uniquely high burdens in Africa, and both have run rampant in recent decades because of a lack of adequate public health response, which in turn has been hampered by the lack of adequate financing of public health measures.

Hunger and disease also interact with low food intake and nutritional deficiencies leading to reduced immune response. High disease burdens (such as infection with soil-transmitted parasites) result in reduced nutritional intake [2]. High child mortality blocks the demographic transition to low fertility rates, and rapid population growth and large families exacerbate poverty. Finally, poverty also contributes to poor governance which in turn exacerbates poverty. The result is a poverty trap in which poverty, hunger,

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[2] UN Millennium Project, Investing in development. A practical plan to achieve the Millennium Development Goals (Earthscan, 2005).

[3] UN Millennium Project, *Halving Hunger - it can be done.* Task Force on Hunger (Earthscan, 2005). PA Sanchez, MS Swaminathan, *Science* 307:357 (2005); Lancet 365: 442 (2005).

[4] UN Millennium Project, *Combating AIDS in the developing world* (Earthscan, 2005),

[5] UN Millennium Project, Coming to grips with malaria in the new millennium (Earthscan, 2005).

[6] UN Millennium Project, *Health, dignity and development: what will it take?* Task Force on Water and Sanitation (Earthscan, 2005).

[7] UN Millennium Project, *Energy services for the Millennium Development Goals.* (World Bank, 2005).

disease, rapid population growth, environmental degradation, and poor governance are all mutually reinforcing. The "Washington consensus" imposed by the Breton Woods institutions during the 1980's and 1990's did not address these underlying factors, and did not enable tropical sub Saharan Africa to escape from the poverty trap [1].

**Approach:**

The underlying hypothesis of the UN Millennium Project is that the multifaceted nature of poverty in rural Africa can be overcome through targeted public-sector investments to raise rural productivity, leading to increased private-sector savings and investments. By significantly augmenting the capital stock of households and the community in several dimensions, the poverty trap can be escaped. Several kinds of capital need to be increased: natural (soil nutrients), infrastructure (roads, power, telecoms), human (skills and health), and financial (household assets, collateral, microfinance). The key is to raise the capital stock above a threshold level, above which the village can move towards self-sustaining economic growth[8]. Ideally this would be carried out on a large scale, involving an entire region or nation in capital accumulation along these lines. The UN Millennium Project recommended that such capital investments be made at an appropriate magnitude and time scale, tackling all sectors with costs shared by communities, governments and donors [1]. This approach contrasts with projects that emphasize macroeconomic stability or incremental steps in a single sector.

Such public investments at scale initiate a positive dynamic of saving and growth which supports private sector investments in two ways. First, household incomes rise above subsistence, so that household-based capital accumulation and microfinance become feasible. Second, the existence of good roads, power and telecoms encourages the inflow of capital from outside investors. The initial economic takeoff usually occurs in agriculture with the transformation of sub-subsistence communities into commercial farming communities which are able to save, invest, and diversify into productive non-farm work The public-sector investments are designed to stimulate, rather than replace, private-sector investments. In this sense, the project is consistent with a market-based and mixed-economy strategy of economic development. These investments are underpinned by 3 major science-based initiatives: Africa's green revolution[9], the worldwide advances in treating malaria, HIV-AIDS and neglected tropical diseases [3, 4], and improvements in information technology.

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[8] JD Sachs et al., *Brookings Pap. Econ. Act.* 1, 117 (2004). JD Sachs, *The End of Poverty* (Penguin, 2005). CB Barrett, BM Swallow, *World Dev.* 34: 1 (2006). MR Carter, CB Barrett, *J. Dev. Stud.* 42:178 (2006).

[9] *Africa's Green Revolution: A call to Action* (MDG Centre, Nairobi, 2004). Secretary-General calls for "Uniquely African green revolution in 21st century to end the Continent's plague of hunger" Addis Ababa. UN Press Release, July 6, 2004. *www.unmilleniumproject.org/html/addis/documents/shtm.*

**Table 1. Recommended level of investment for rural African villages by the United Nations Millennium Project (1)**

| Interventions | U.S. $ per person per year | U.S. $ per year per village of 5,000 people |
|---|---|---|
| Household share: | 10 | 50,000 |
| Government share: | 30 | 150,000 |
| Donor share: | 70 | 350,000 |
| Total investment | 110 | 550,000 |
| Distribution by sector | | |
| Agriculture and nutrition (15%) | 17 | 82,500 |
| Health (30%) | 33 | 165,000 |
| Infrastructure (energy, transport, communications) (20%) | 22 | 110,000 |
| Education (20%) | 22 | 110,000 |
| Water, sanitation, environment (15%) | 17 | 82,500 |

The MVP contributes $50 of the $70 donor share.

In March 2004, the MVP was developed as a proof of concept that the poverty trap can be overcome and the MDGs achieved by 2015 at the village-scale in rural Africa by applying the UN Millennium Project's recommended interventions in multiple sectors[1] at the investment level of $110 per capita per year sustained over a period of 5 to 10 years (**Table 1**). The main principles of the MVP are:

- Science- and evidence-based, implementing technologies and practices that have already been proven.
- Community-based, with a participatory approach to planning, implementation and monitoring that contextualizes the specific set of interventions for each village,.
- Enhanced by local capacity-development in technical, managerial, and participatory skills.
- Based on multi-sectoral and integrated interventions.
- Geared toward gender equality and environmental sustainability
- Linked to district, national, and global strategies.
- Supported by partnerships with other development groups.
- Cost-shared by the community, government and donors.
- Supported by increased national-scale financing of public goods in line with increased Official Development Assistance (ODA) made available to African governments.

**Strategy:**

The strategy focuses on four interconnected challenges: agricultural productivity, public health, education and infrastructure. The interventions are undertaken as a single integrated project; the synergies and tradeoffs are assessed and highlighted before decisions are made. For example, higher food production

has positive impacts on health and education, but might also result in children missing school by working on farms. Impacts of interventions on gender and the environment are sometime less obvious but critical for long term sustainability. Where adverse cross-sector tradeoffs are possible there must be guidelines and incentives or disincentives to minimize them.

Not all interventions can start at the same time and are phased according to local conditions and priorities. The first phase (usually 12 – 18 months) involves the basics---food, health, water and community empowerment. A generic list of interventions, which are localized for each site, follows:

- **Increased food production**. Subsidized provision of improved seeds of high-yielding crop varieties or hybrids, the necessary amounts of mineral and organic fertilizers, and training on best agronomic practices, to eliminate hunger months and generate crop surpluses.
- **Malaria control**. Free distribution of long-lasting insecticide-impregnated bednets (LLIN's) for all sleeping sites, preceded by training and followed by monitoring of use, combined with access to anti-malaria medicines, to drastically reduce the disease burden of malaria.
- **A functional clinic** at the village level, staffed by government and community health workers, to provide basic clinical services for infectious diseases, nutritional deficiencies, antenatal care, and attended normal delivery.
- **Safe drinking water points** constructed with the eventual aim of having access within 1 km of each household.
- **Community capacity-building,** to empower villagers to manage their own development more effectively; and to enhance the sustainability of interventions.

Another set of interventions follows, building on the first set, and others from additional sectors.

- **More robust and diversified agriculture** using nitrogen-fixing trees and cover crops, organic manures, crop rotations, soil conservation practices, livestock, small-scale water management, improved crop storage, and crop insurance.
- **Expanded health systems,** including further malaria control through indoor residual spraying, particularly in epidemic areas; family planning; micronutrient supplementation for vulnerable groups; treatment and prevention of HIV/AIDS and TB; and improvements in the nearby referral hospital, including emergency obstetrical care.
- **Functioning primary schools**: Universal enrolment in primary school , with adequate buildings, teachers, materials, separate latrines for girls and boys, drinking water, and a nutritious mid-day meal from locally produced food.

- **Improved clean water, sanitation and personal hygiene.** Access to sufficient clean water for domestic consumption, pit latrines at home, and sanitary napkins for adolescent schoolgirls.
- **Infrastructure**: Upgrading local roads and improving access roads, connecting to the electrical grid and the internet; transportation to and from markets.
- **Expanded links with government and other development partners**: Steering groups that coordinate local and district-level activities, planning and cost-sharing.
- **Commercial farming and business development**: Diversifying farm enterprise toward high-value products and linking producer groups to markets. Enterprise development through capacity building, access to microfinance and micro-enterprise institutions.
- **Environmental rehabilitation**: Increasing tree cover, soil conservation structures, agrobiodiversity and carbon sequestration.

**Table 2. Baseline conditions (2004) by income quartiles for the Sauri Millennium Research Village population**

| Parameter | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|
| Yearly per capita income (U.S. $, PPP) | 39 | 113 | 231 | 959 |
| Income from agriculture, % | 68 | 52 | 43 | 24 |
| Average land holding, ha | 0.52 | 0.53 | 0.57 | 0.71 |
| Area planted to maize, ha | 0.23 | 0.22 | 0.25 | 0.27 |
| Maize yields, kg $ha^{-1}$ | 1.81 | 1.85 | 2.02 | 2.09 |
| Anemia (<11 mg Hb), % | 46 | 47 | 49 | 37 |
| Testing positive for malaria, % | 56 | 49 | 52 | 41 |

Results from household surveys, maize harvest estimates, and blood sampling (21). Q1 denotes the lowest income quartile. PPP, purchasing power parity.

The first Millennium Villages were established in Sauri, Kenya in December 2004, and in Koraro, Ethiopia in February 2005, with additional villages in 2006, for a total of 12 located in Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Rwanda, Senegal, Tanzania and Uganda (see Supporting Information). Each site is in a major agro-ecological zone that together represent the farming systems used by 90% of the agricultural population and 93% of the agricultural land area of Sub-Saharan Africa [10]. The sites range from slash-and-burn in rainforest margins to pastoralism in deserts and represent different situations of population density, soils, climate, water access, disease complexes and burdens, environmental degradation, market access, education levels, cultures, religions and gender issues. Together the 12 research villages provide a robust framework for proof of concept.

[10] Calculated from J Dixon, A Gulliver, D Gibbon, *Farming systems and poverty* (FAO, 2001).

**Initial Results:**

This section includes results from the Sauri baseline survey[11], annual reports from Sauri[12] and Koraro[13] and crop harvest data from Malawi[14]. In 2004, almost 80% of the population of Sauri lived below the one-dollar-a-day poverty line [11]. Land holdings were less than 0.6 ha for 75% of the households with 0.22 to 0.27 ha planted to maize, the staple food crop in 2004. Maize grain yields were under 2 t $ha^{-1}$ with a 0.3 t difference between the lowest and highest income quartile (**Table 2**). Over half of the blood smears from the sample population in Sauri tested positive for malaria parasites, with the highest prevalence found in the lowest income quartile. Only 13% of the households reported having malaria bednets [11]. The high levels of anemia, almost 50% of the three lowest income quartiles, are another indication of the high levels of malaria, undernutrition, and intestinal parasites.

**Health:**

Before the project, the nearest health services were provided at the Yala Sub-district Hospital (no electricity, water or doctors) at a distance of around 5 km. The Sauri Community Dispensary was opened in July 2005, with the Ministry of Health providing a clinical officer, the MVP funding 2 nurses and a laboratory technician, and the community providing community health workers. In the first year, 35,476 patient cases were seen, of whom 72% were Sauri residents [12], the others came from surrounding, non-project villages. The most common diseases treated were malaria, respiratory tract infections, skin conditions, intestinal worms and diarrhea.

There was no marked difference in malaria prevalence among residents from Sauri that had received bednets and those from outside Sauri until October 2005 (**Fig. 1**). After that date, malaria prevalence among Sauri residents tested at the clinic fell to one-third of that of non-Sauri residents who did not receive bednets. In Koraro, Ethiopia a clinic did exist, but had essentially no staff or medicines. In 2005, the Ministry of Health assigned a medical officer, three nurses and a laboratory technician and 5780 patients were treated as compared with 260 patients the previous year [13]. Prior to bednet distribution in September and October (the two months of peak malaria transmission) of 2005, there were 281 diagnostically confirmed malaria cases seen in the clinic. During the same period of 2006, there were only 143, a 51% reduction [13].

**Agriculture:**

The results of the initial harvests in 3 research villages are shown in **Table 3** in comparison with estimates from the pre-project year. In Sauri, 2005 maize yields increased 2.6-fold from 2004, averaging 5.0 t $ha^{-1}$ at the village scale (325 ha).Given the availability of inputs for each field they chose to plant, Sauri

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[11] P Mutuo, E Lelerai, H Okoth, J Oule, BA Ouma, J Wangila, CA Palm, K Wang, B Konecky et al, *Baseline report Sauri Millennium Research Village*. Earth Institute at Columbia University (New York, 2006).

[12] P Mutuo, H Okoth, C Makomere, J Oule, G Oduong, W Ombai, J Wariero, B Akinyi (2006) *Annual report for Sauri, Kenya Millennium Research Village July 2005-June 2006.* Earth Institute at Columbia University (New York, 2006)

[13] T Kiflemariam, A Gebretsadik, G Kebede, G Mehari, T Habtetsion, Y Ye-ebiyo, A. Said, H Desta, *Annual report for Koraro, Ethiopia Millennium Research Village July 2005- June 2006* Earth Institute at Columbia University (New York, 2006).

[14] R. Harawa et al., *Mwandama Millennium Villages 2006 Annual Report,* Earth Institute at Columbia University (New York, 2007).

farmers increased their area planted to maize by almost 50%, all from fields that had been abandoned because of low soil fertility and related weed infestation. The combined effect was a village-wide 3.9-fold increase in maize production and a shift from 43 to 166% of the basic caloric requirements (**Table 3**).

All income groups of farmers increased their yields by a similar amount and yields were similar among income quartiles [12]. On average families in the lowest income quartile produced 1.8 t of maize, surpassing the 1.1 t requirement for basic food security for a family of 5.7 people. A minimum land area of 0.21 ha is needed to produce that amount of maize for food security and one-third of the households had insufficient area.

The fact that pre-intervention yields were similar across income groups and that yields increased similarly across income groups suggests two important points. First, even the relatively wealthy households ($2.6 per day) were not using fertilizer and high-yield seeds before the project; and second, even the poorest households ($0.11 per day) can effectively utilize subsidized agricultural inputs and training.

In 2006, yields were even higher, with an average yield of 6.2 t $ha^{-1}$ (**Table 3**) The area planted increased by about 10% above the 2005 area. In 2006 the village surplus was almost 1300 t and the minimum area needed to produce 1.1 t was reduced to 0.18 ha, meaning that only 27% of the households had insufficient area to reach basic food security.

The cost of this upfront investment in fertilizer and seeds supplied by the project was $50 per household planting an average of 0.25 ha to maize in 2005. Approximately 11% was paid back through contributions of surplus maize to the school meals program, representing a net subsidy of 89%. For the 2006 maize crop, the subsidy for fertilizer and seed was reduced to $37. Some farmers did buy fertilizer and improved seed from the market. In the third year seed and fertilizer subsidies were eliminated for the households in the top three income quartiles, while still fully subsidizing those very small and vulnerable ones. Farmers either purchased inputs or obtained loans from a microfinance provider.

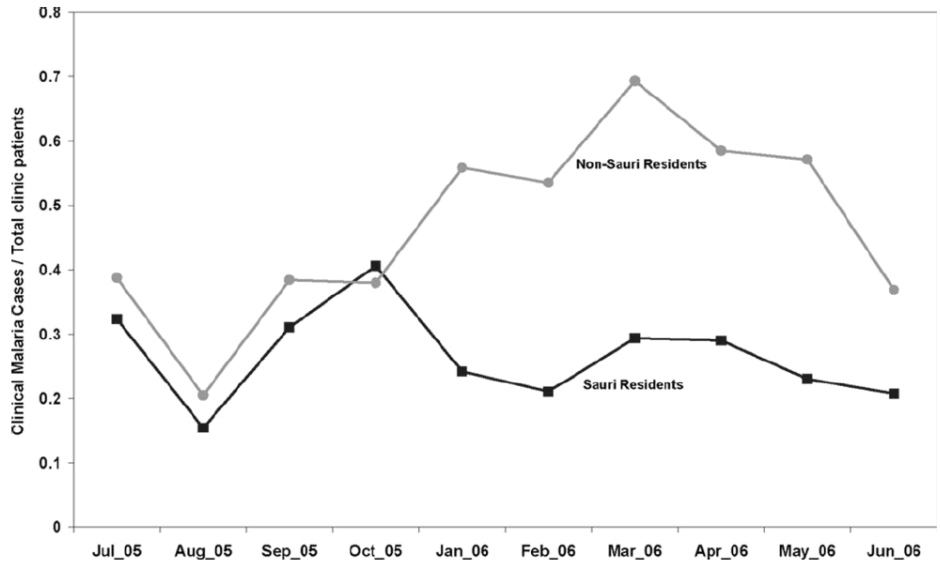


**Fig. 1.** Malaria prevalence from July 2005 to June 2006 for Sauri Millennium Research Village residents and those from outside. Prevalence is the percentage of those treated or tested positive for malaria relative to the total number of patients seen at the dispensary. No data were obtained in November and December 2005 because of generator breakdown.

**Table 3. Basic food production increases in the first three villages' harvests**

| Millennium Research Village | Year pre-project* | Grain yields, t·ha$^{-1}$ | Area planted, ha | Production, t | Production increase (times from *) | Caloric food requirement index |
|---|---|---|---|---|---|---|
| Sauri, Kenya | 2004* | 1.9 | 220 | 418 | | 0.43 |
| | 2005 | 5.0 | 325 | 1,625 | 3.9 | 1.66 |
| | 2006 | 6.2 | 364 | 2,257 | 5.4 | 2.31 |
| Koraro, Ethiopia | 2004* | 0.13 | 1067 | 139 | | 0.13 |
| | 2005 | 0.58 | 1970 | 1148 | 8.3 | 1.10 |
| Mwandama, Malawi | 2004/5* | 0.8 | 690 | 552 | | 0.56 |
| | 2005/6 | 6.5 | 1272 | 8268 | 15.0 | 8.46 |

Data are for maize (*Zea mays*) in Kenya and Malawi and an average of teff (*Eragrostis tef*), sorghum (*Sorghum vulgare*), finger millet (*Pennisetum* sp.), and maize in Ethiopia. Caloric food requirement index is the ratio of production to food needs (978 t of maize per 5,000 people or 1,045 t of grains in Ethiopia).

**Koraro**, Ethiopia is a degraded highland semiarid area with highly variable rainfall. The 2004 year was a severe drought year, yields of the four main cereal grain crops were 0.13 t ha$^{-1}$, producing only 418 t of grain which met 13% of the village's caloric food requirement. In 2005, with inputs and good rainfall, average yields quadrupled but still a low level of 0.58 t ha$^{-1}$ (**Table 3**). Koraro farmers also increased their area planted 1.8-fold, resulting in an 8.3-fold increase in total production over 2004. Basic food requirements for the village were met. A partition of the yield increases in teff, the main cereal crop, indicates that the effect of a good rainy season without inputs resulted in a yield increase from 0.08 to 0.41 t ha$^{-1}$. The use of fertilizer without improved seeds, increased teff yields further to 0.59 t ha$^{-1}$, but the full

intervention package of fertilizer plus improved seeds combined with good rains resulted in an average yield of 1.20 t $ha^{-1}$, a 15-fold increase [13].

**Mwandama**, Malawi suffered from a drought in the year preceding the start of the project. Even in good rainy seasons, however, the perennial nitrogen "drought" (i.e. shortage of nitrogen in the soils) result in low maize yields. In the first planting season maize yields increased from 0.8 to 6.5 t $ha^{-1}$, and the area planted almost doubled, the total maize production increased 15-fold (**Table 3**). Maize yields from farms not using improved seeds and fertilizers averaged 2.2 t $ha^{-1}$, showing that good rains alone accounted for less that half of the yield increase[14]. No one expects that these village average yields to be replicated at the country scale. Malawi did institute a voucher-based 75% subsidy on fertilizers and improved maize seed for the 2005/6 season and as a result national maize production doubled and average maize yields doubled from 0.73 to 1.61 t $ha^{-1}$.[15]

Crop surpluses minimize risks of food shortages in subsequent years but also serve as the entry point for entering the cash economy. Bumper crops also can result in drastic reductions in crop prices, leaving farmers with their surpluses unsold [2]. In Sauri, farmers were offered only $10 per 90-kg bag of dry maize in August 2005 by local middlemen, less than the official price of about $20. In need of cash to buy essentials farmers normally sell at these prices only later to run out of food and buy back maize for as high as $25 a bag. To buffer such price fluctuations, a cereal bank was established by renting storage space and using project funds to pay farmers the equivalent of $17 per bag. The cereal bank sold the crop at $21 per bag in April 2006, farmers were paid the difference, minus storage and management fees, effectively doubling the price they would have received selling to middlemen [12]. In Ethiopia a 5-ton truck provided by the project allowed farmers to transport their surplus crop of 84 tons of teff and finger millet which was sold at $39,528 [13].

Following increased food production, diversification to higher-value crops is being promoted. Sauri farmers have organized producer groups for onion, tomato, banana, dairy, and mushrooms. Many farmers are now shifting about one third of their maize land to these high-value products. Microfinance mechanisms, including but not limited to micro-credit are being established, including training in record keeping and accounting. Crop insurance schemes are being developed to reduce risks of future crop failures caused by drought.

**Discussion:**

The MVP aims to demonstrate the feasibility of practical economic transformation in rural tropical Africa through targeted multisectoral investments. This approach has similarities and differences with the Integrated Rural Development (IRD) approach of the 1970's and 80's. The main similarities are simultaneous, complementary interventions, which create synergies and a major initial focus on agricultural productivity, including agro-processing[16][17].

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[15] GL Denning et al., Investing in Smallholder Agriculture to Achieve National and Household Food Security: Malawi's Contribution to an African Green Revolution (MDG Centre, Nairobi, 2007).

[16] DA Rondinelli, *World Politics*, 31, 389 (1979).

[17] J Sallinger-McBride, LA Picard, *Comparative Politics*, 22:1 (1989).

IRD projects were developed by a range of donors and governments with different priorities, resource allocations, designs, execution and duration. In contrast, the MVP model is focused on achieving time-bound and quantitative goals, and promotes a more comprehensive set of sectoral interventions. Many IRD projects focused on more prosperous areas; World Bank programs, for example, were often based in high growth areas [18]. Also, within chosen areas, IRD projects often failed to be pro-poor[19]. In contrast, the Millennium Villages are situated in hunger hotspots where at least 20% of children under 5 are underweight [2].

IRD projects were often based on insufficient experience with local agricultural systems[20] and the new farming interventions had seldom been tested with smallholders[21]. MVP interventions are drawn from technologies and practices that have been proven under similar ecological and socioeconomic conditions. While IRD projects were typically top-down, government and community participation is a major feature of the MVP. Ownership can be generated by communal efforts and in-cash, in-kind contributions[22], a feature of MVP.

The 5–10 year commitment of the MVP is longer than the 2-3 year duration of IRD projects. Although the scale of investment of IRD projects is unclear they were probably funded at much lower levels than MVP. Beyond these differences, the MVP approach can benefit from three key developments since the IRD era: (i) decentralization and devolution of authority to local government; (ii) internationally agreed financial commitments to double ODA in Africa by 2010, and then further increases to 2015, and (iii) major advances in environmentally-sound agriculture, health and information technology.

There have been many attempts to bring a green revolution to Africa[23]. The Asian green revolution benefited from high yielding crop varieties, fertile alluvial soils, and irrigation, with crop improvement accounting for 66 to 88% of the yield increases[24], The green revolution in Africa has not benefited similarly from improved crop varieties [24] but must also redress nutrient depleted soils [7] and little to no irrigation. There is abundant evidence throughout Africa on crop yield response to fertilizers, both organic and mineral[25]. The MVP promotes overcoming nutrient limitations by sufficient rates of both

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[18] T Mkandawire, *The World Bank and Integrated Rural Development in Malawi*, Working Paper No. 1. (Council for the Development of Economics and Social Research in Africa, Dakar, 1980).

[19] JA Binns, DC Funnell, *Geografiska Annaler* B 65,57 (1983).

[20] Williams, G., "The World Bank and the peasant problem," Chapter 2, in J Heyer et al. (eds.), Rural Development in Tropical Africa.(Macmillan, 1981).

[21] DFID, "*Synthesis of Integrated Rural Development Projects*," Evaluation Summary 438, http://www.dfid.gov.uk/aboutdfid/performance/files/ev438s.pdf . "*Rural Development in Africa: A Synthesis of Project Experience*," Evaluation Summary 400. http://www.dfid.gov.uk/aboutdfid/performance/files/ev400s.pdf. (DFID, 2004).

[22] EW Bresnyan, MA Bouquet, F Russo, "MBOPs and the case of NE Brazil: The Rural Poverty Eradication Program," (World Bank, 2003).

[23] G Conway, *The doubly green revolution; food for all in the 21st century* (Penguin, 1997). G Conway, G. Toenniessen, Science 299: 1187 (2003). G Djurfeldt, H, Holmen, M Jistro, R. Larsson, *The African food crisis. Lessons from the Asian green revolution* (CABI, Wallingford, UK 2005).

[24] RE Evenson, D. Gollin (eds.), *Crop variety Improvement and Its effect on productivity: the Impact of international agricultural research* (CABI, Wallingford, UK, 2001).

[25] RJ Buresh, PA Sanchez, FJ Calhoun, (eds.), *Soil fertility replenishment in Africa*, Spec. Pub. 51, Soil Science Society of America (Madison, Wisconsin, 1997). PA Sanchez, RJ Buresh, RRB Leakey, *Philosophical Transactions of The Royal Society*,

mineral and organic sources of nutrients[26]. Mineral fertilizers are distributed the first year and legume cover crops and trees and composts are promoted the second year. Some programs have advocated small quantities of nutrients to get farmers used to fertilizers but at rates insufficient for high yields[27]. Others promoted full rates of plant nutrients and improved seed that have usually produced bumper crops[28], but in some cases this resulted in collapsing prices so farmers lost money and were unable to pay back their loans (2). To address this challenge the MVP interventions include a cereal storage and marketing strategy to buffer price fluctuations in anticipation of the bumper harvests.

Results are still early, though the initial agriculture revolution has began in most sites with high yields and crop surpluses. Crop surpluses were used to initiate school meals programs. Positive interaction between improved labor productivity (less malaria) and land productivity allow agricultural activities to intensify. The subsequent phases of crop diversification and linking farmers to markets are challenges that have escaped most IRD projects but are essential to overcome the poverty trap and achieve the MDGs at the village level.

Targeted input subsidies are necessary to jump-start increased food production and to sustain yields of both food crops and high-value agricultural products [2]. The strategy is to subsidize fertilizers, improved seeds of maize, vegetables, grain legumes, nitrogen-fixing trees, treadle pumps and other inputs through local dealers and provide them with technical training —making a network of agrodealers in rural Africa [16]. One approach is to use vouchers with information on the farmer's eligibility for subsidized inputs, limiting them to 1 or 2 bags of fertilizer and 10 kg of improved seed, magnitudes of inputs that are too small to interest large-sale commercial farmers. The vouchers are redeemed for inputs at agrodealers, who get paid by the banks where the subsidies are deposited by governments or donors. Such smart subsidy systems overcome many of the mistakes of the past and empower the private sector. Partnerships are being developed with companies working across the food chain to ensure quantity, quality, and timely delivery of products.

**Limitations of Project Design**

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The MVP is a highly complex project, and as such, faces several limitations recognized at the outset. Here we mention scale and controls. First, the scale of each project site (a cluster of a several villages totaling 5,000 – 55,000 people) is determined by available project financing and implementation capacity, but poses several limitations. The sites are not large enough to justify large-scale infrastructure (e.g. a new water-treatment facility) or to justify inflows of foreign buyers for sourcing agricultural-based primary commodities, or to promote foreign investments in processing facilities. They are vulnerable to inflows of people from surrounding areas and might generate resentment in surrounding communities. Finally, the project remains vulnerable to political upheaval and to drought which could be better cushioned with national-scale interventions. For these reasons, we should expect that a larger-scale effort than MVP would benefit from important economies of scale that will not be evident in the MVP alone. The scaling up of the key interventions to district and national level is discussed below.

For ethical and practical reasons, there are no formal "control" villages, though there is monitoring of district-based indicators to obtain quantitative and qualitative comparisons with the project sites. Measurements are based on before-and-after comparisons, and detailed studies by sector, rather than control-vs.-non-control villages. The ethical reasons relate to the fact that many core interventions (e.g. malaria control, access to safe water) are life saving, and would be ethically inappropriate to deny in a control village. Moreover, it would not be practically and politically feasible to be deeply involved in monitoring a control village without also offering a substantial package of beneficial interventions, especially in light of the intervention package offered in the intervention villages.

Nor are individual interventions randomized across or within villages to try to get intervention-specific impacts. In some cases (e.g. the impact of fertilizers and seed varieties on crop yields) the data will allow us to assess the impact of specific interventions. In other cases (e.g. anemia), the outcome will result from several interventions (de-worming, food intake, nutritional supplements, malaria control) and factor-specific responses will be less clear. The fact that key outcomes have multiple and synergistic causes is even more true for more complex outcomes such as school attendance and school performance.

**Sustainability**

One of the complex issues regarding the MVP is the exit strategy for external donors. The project commits to five years of funding, and anticipates that the community will become economically self-sustaining in commercial farming and non-farm activities within that period. We hypothesize that farmers will be able to procure inputs and sell outputs on a normal market basis at the completion of the first five years of the project, based on higher productivity and greater product diversity. Subsidies of farm inputs may continue as part of national policy, but should no longer be necessary from the project itself.

The community, however, will not be able to bear the financing for the interventions in health, education, and infrastructure. Rather, the national governments should, by the fifth year of the project, have national financing of such interventions out of an expanded budget for such priority investments. All governments in the world are committed to achieving the MDG's and the rich countries are committed to a significant increase of ODA to support the MDGs in the poorest countries. Thus, by 2011 (the sixth year of the project for the current Millennium Villages), the aid received by Africa should be more than double

the 2005 levels, reaching at least $50 billion per year (a per-recipient equivalent of $75-100). This increased aid will be directed in part to expanding government support for critical services in health, education, infrastructure, and that expanded national budget should substitute for financing provided by the MVP in the years to 2011.

**Scalability**

Chances for success of the MVP depend, naturally, on whether the increased government budgets or ODA for public goods actually materializes, and whether the types of interventions pioneered by the MVP are thereby expanded to other rural areas in the host countries. If the villages remain islands of prosperity in a sea of unrelenting poverty, then they are more likely to be over-run by in-migration and undermined by neighborhood jealousy. If instead the Millennium Villages are part of an expanded national-scale effort to achieve the MDGs, then they will benefit from an expanding national market, increased social and political stability, improved national-scale infrastructure, and success in attracting private investments that connect the villages with regional and international markets.

As part of the overall Millennium Project, a senior country advisor based in the capital of each of the 10 countries works with government to assist in bringing the MDGs into the budget and policy process, as well as providing a link to the Millennium Villages. To encourage that expanded scale, two additional initiatives are being launched. The Millennium Cities Initiative works with the major regional city closest to the Millennium Villages, in order to improve the urban business environment, to attract foreign investments into the city, and in part to create a market for the increased outputs of the villages and surrounding areas. After the first year of the project several countries in which Millennium Villages are located are working with the donor community and using their own resources to establish additional villages and also to scale up from the village scale (5,000 people) and "cluster" scale (30,000 -50,000 people) to a Millennium District scale (300,000 - 500,000 people). With interventions applied at a district scale, not only will there be a greater scope of the market, and improved chances for a productive division of labor, but also improved chances for attracting inflows of foreign investment, and for undertaking public investments in roads, power, telecoms, and other sectors, where the scale of investments exceeds what can be accomplished at the village scale.

**Methods:**

The following methods are described for the first research village in Sauri, Kenya, but apply as standard protocols and generic intervention strategies for all villages. See Supporting Information for site selection.

**Baseline Assessments:**

Before intervention activities begin, comprehensive baseline assessments are conducted through household surveys, anthropometric and biophysical measurements (see Supporting Information). These surveys are used to determine baseline MDG initial conditions and targets to meet the MDGs and to monitoring impact of interventions. Repeat surveys will be administered in year 3 and 5 (and 10). The content of the survey modules is summarized in Supporting Information. Health baseline data also include

blood samples to determine nutritional status, levels of anemia, malaria parasite types and infection levels; weights and heights of children less than 5 years, and stool samples for determining parasite loads.

An initial demographic survey provides information to stratify the population according to geographic representation and wealth categories. The wealth categories are determined by identifying assets considered important by each of the communities. A comprehensive socioeconomic survey is administered to all households, while the remaining surveys are administered to a stratified sub sample of 300 households –determined by geographic and wealth criteria.

**Malaria control---first phase:**

In Sauri from May to July 2005, 3000 Olyset long lasting insecticide-impregnated bednets were distributed free to all households to cover all sleeping sights, roughly 3 nets for every 5 people. Nets were distributed after training sessions on malaria prevention, treatment and bednet use by community health workers. The bednets were distributed free of charge because they constitute a public good like immunizations due to their "mass effect" on malaria control at the community level (30).

The impact of the LLIN bednets was determined by comparing malaria incidence of the patients that came to the clinic in Sauri between those that had received bednets (Sauri residents) and those that had not received bednets (nonresidents). Malaria was diagnosed by clinical symptoms and for the questionable cases was confirmed by examination of blood smears for presence of malaria parasites.

**Agriculture – first phase:**

Sauri farmers were provided with 96 kg N $ha^{-1}$ and 50 kg P $ha^{-1}$, as diammonium phosphate and urea for topdressing, the full recommended rate of mineral fertilizers for these nitrogen depleted and high phosphorus-fixing Oxisols and oxic Alfisols. In addition they received high-yielding hybrid maize seed (WS 502 and WS 505) from a local seed company. Farmers also requested training on the best agronomic practices, which was done by agricultural extension agents prior to planting. Upon receiving the agricultural inputs each farmer signed a document agreeing to use them in their fields and return 10% of their crop surplus to the village schools for the feeding program. Similar arrangements took place in the other villages.

Crop yields were estimated 2-4 weeks prior to harvest from 30-90 farms which have used fertilizer, improved seed and training. This sample is again stratified according to wealth and geographic criteria. In addition, crop yields are estimated from a minimum of 30 farms that did not use improved agricultural inputs. Crop estimates per farm are obtained by taking two to three samples from 5 x 5 m quadrants randomly placed within the maize field. Sub-samples of the cobs and grain are taken and dried to determine grain yields at 14% moisture content.

Basic food security for the maize–based villages of Sauri and Mwandama was estimated as the difference between the amount of maize produced and the caloric requirements for the 5,000 people,

assuming 2500 calories per person per day[29], and that 75% of the caloric requirement is met through consumption of maize, as reported for Western Kenya[30], and that 1 kg of maize provides 3500 calories[31].

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