CHAPTER THREE

The African Green Revolution: Results from the Millennium Villages Project

Genererose Nziguheba,[*] Cheryl A. Palm,[*] Tadesse Berhe,[†] Glenn Denning,[*] Ahmed Dicko,[‡] Omar Diouf,[§] Willy Diru,[¶] Rafael Flor,[#] Fred Frimpong,[||] Rebbie Harawa,[**] Bocary Kaya,[‡] Elikana Manumbu,[††] John McArthur,[*,‡‡] Patrick Mutuo,[¶] Mbaye Ndiaye,[§] Amadou Niang,[#] Phelire Nkhoma,[**] Gerson Nyadzi,[††] Jeffrey Sachs,[*] Clare Sullivan,[*] Gebrekidan Teklu,[†] Lekan Tobe,[§§] *and* Pedro A. Sanchez[*]

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[*] The Earth Institute, Columbia University, New York
[†] MVP Koraro cluster, Center for National Health Development, Addis Ababa, Ethiopia
[‡] MVP Tiby Cluster, Segou, Mali
[§] MVP Potou cluster, Louga, Senegal
[¶] MVP Sauri cluster, Kisumu, Kenya
[#] MDG Center for West and Central Africa, Bamako, Mali
[||] MVP Bonsaaso Cluster, Manso-Nkwata, Ashanti, Ghana
[**] MVP Mwandama Cluster, Zomba, Malawi
[††] MVP Mbola Cluster, Tabora, Tanzania
[‡‡] Millennium Promise, New York, USA
[§§] MVP Pampaida Cluster, Zaria, Kaduna State, Nigeria

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Abstract

The Millennium Villages Project (MVP) was initiated in 2005 to implement the recommendations of the UN Millennium Project for achieving the Millennium Development Goals (MDGs). The project is carried out in 14 sites in hunger and poverty hotspots in diverse agroecological zones in sub-Saharan Africa (SSA). The interventions and results for increasing staple crop yields are presented for eight MV sites and cover 52,000 farming households or 310,000 people. By supporting farmers with fertilizers, improved crop germplasm, and intensive training on appropriate agronomic practices, average yields of 3 t ha^{-1} were exceeded in all sites where maize is the major crop. Teff yields doubled in the Ethiopian site. In contrast, there was little improvement in millet and groundnut yields in the semiarid and arid sites in West Africa. Over 75% of the farms had maize yields of 3 t ha^{-1} and less than 10% of the households had yields lower than 2 t ha^{-1}. Households produced enough maize to meet basic caloric requirements, with the exception of farms smaller than 0.2 ha in Sauri, Kenya. Value-to-cost ratios of 2 and above show that the investment in seed and fertilizer is profitable, provided surplus harvests were stored and sold at peak prices. Increased crop yields are the first step in the African Green Revolution, and must be followed by crop diversification for improving nutrition and generating income and a transition to market-based agriculture. A multisector approach that exploits the synergies among improved crop production, nutrition, health, and education is essential to achieving the MDGs.

1. Introduction

In most parts of the developing world, per capita staple food crop production has increased steadily over the past four decades. This increase is largely the result of Green Revolution technologies, including high-yielding crop cultivars, irrigation, fertilizers, mechanization, and pest and disease control, supported by enabling government policies (Hazell and Wood, 2008). Sub-Saharan Africa (SSA) is the only region where per capita production has barely changed (Hazell and Wood, 2008; Jaeger, 1992). While populations continue to grow, yields of major crops remain very low in SSA with average cereal yields of less than 1 t ha^{-1} compared to averages of 3 t ha^{-1} Latin America and South Asia (Hazell and Wood, 2008).

The absence of the Green Revolution in Africa has been attributed to the lack of adoption of improved crop germplasm or even the absence of appropriate varieties for the continent (Sanchez, 2002) but perhaps more pervasive has been the gradual depletion of soil fertility through decades of removing nutrients with crop harvests but not replenishing them through the addition of sufficient amounts of fertilizer, mineral, or organic (Drechsel *et al*., 2001; Sanchez, 2002; Stoorvogel *et al*., 1993). The removal of subsidies for fertilizers in Africa in the 1980s by the "Washington Consensus" structural adjustment programs led to the decline of fertilizer use (World Bank, 2008). Limited physical access to fertilizers has also been identified as a major constraint to the use of fertilizers in many countries in Africa (Larson and Frisvold, 1996). At the Africa Fertilizer summit, a call for increasing the use of fertilizers from the current average of 8 kg ha^{-1} was made to raise agricultural production (IFDC, 2006). If SSA is to feed its population, a major transformation in agriculture production needs to happen.

At the Millennium Summit in 2000, world leaders set forth the Millennium Development Goals (MDGs), quantified and time-bound goals to cut extreme poverty and hunger, reduce disease burden, improve education, gender equality, and reverse land degradation. Although the MDGs have been generally accepted, questions arose regarding how to implement them. In 2002, the United Nations (UN) Millennium Project was commissioned by the UN Secretary General to develop a concrete action plan for the world to achieve the MDGs; task forces were convened to provide recommendations for each of the MDGs. Recommendations from each of the task forces were published in separate reports and summarized in the *Investing in Development* report (UN Millennium Project, 2005a).

Currently, Africa is the only continent severely off-tract to reach the goals (MDG Africa Steering Group, 2008). Several biophysical and policy constraints limit the ability of most African countries to escape from hunger, extreme poverty, and disease; extremely low food production being at the top (Jayne *et al*., 2003; Larson and Frisvold, 1996; Sachs *et al*., 2004).

Drawing on the work of the UN Millennium Project Hunger Task Force (Sanchez and Swaminathan, 2005; UN Millennium Project, 2005b), the then Secretary General of the UN, Kofi Annan, made a call for a uniquely African Green Revolution that provided the framework for Africa to achieve the MDG 1, the eradication of extreme poverty and hunger (MDG Center of East and Southern Africa, 2004). The Hunger Task force made seven major recommendations toward the hunger eradication goal:

- Moving from political commitment to action.
- Reforming policies and creating an enabling environment.
- Increasing the agricultural productivity of food-insecure farmers, focusing first on soils and water.
- Improving nutrition for chronically hungry and vulnerable groups.
- Reducing the vulnerability of the acutely hungry through productive safety nets.
- Increasing incomes and making markets work for the poor.
- Restoring and conserving the natural resources essential for food security.

The Millennium Villages Project (MVP) was initiated in 2005 as proof of the concept that, by applying the recommendations from all the UN Millennium Project Task Forces in impoverished rural communities in Africa, they can achieve the MDGs at a local scale by 2015 (Sanchez *et al.*, 2007). The sites were chosen from among hunger hotspots (defined as more than 20% of children under the age of five as underweight for age) that were identified by the UN Millennium Project Hunger Task Force to represent the diverse agroecological zones and farming systems in Africa, as defined by Dixon *et al.* (2001).

The MVP is community-based and applies science- and evidence-based interventions in health, education, agriculture, road and electricity infrastructure, information technology, water and sanitation, and the environment. The community-based approach used in the MVP follows well-established principles of participation, social and gender inclusion, equity, and local stakeholders' ownership of the decision-making and development processes. Communities are involved in all steps of the project, including assessments and priority setting, planning, implementation, monitoring, and evaluation of project activities. Before implementation, communities went through a self-analysis process in which they determined the resources available within and outside the community, and identified their main priorities. Project staff (all nationals of the countries) work with the communities to assess potential interventions for the local situations, taking into account short- and long-term objectives, and cost effectiveness. Subsequent steps consisted of developing community action plans to address these priorities and the steps needed to achieve the MDGs by 2015.

Community-based institutions or leaders were identified and they play important roles in the implementation of interventions. They included traditional chiefs and elders, local government officials, agricultural extension officers, common interest entrepreneurial groups, farmer associations, women groups, youth groups, self-help groups, and Non Governmental Organizations (NGOs) already working in the villages. Local capacity building plays a major role in achieving community ownership.

Before the MVP started, the communities involved typically experienced food shortages for several months in a year, which also had a negative impact on other MDGs, such as health and school attendance, and often led to migration from rural to urban areas, particularly of men and youth. Therefore, increasing agricultural production and achieving basic food needs was one of top priorities identified by communities, followed by improved health care services (Sanchez *et al.*, 2007).

In this review, we focus on the MDG Goal 1 target of halving hunger, the agriculture-related activities carried out to increase food availability, access, and utilization. We summarize the processes, activities, and results of 3–4 years of interventions in several Millennium Village clusters, followed by a discussion of the next steps in the transition from subsistence agriculture to market-based agriculture.

2. Description of the Village Clusters

The MVP operates in 80 villages organized in 14 clusters in Kenya, Ethiopia, Ghana, Malawi, Mali, Nigeria, Senegal, Rwanda, Tanzania, and Uganda (Fig. 1). These villages were selected to represent the principal agroecological zones and farming systems of Africa that are hunger hotspots. Eight clusters (Sauri, Kenya; Bonsaaso, Ghana; Mwandama, Malawi; Pampaida, Nigeria; Mbola, Tanzania; Tiby, Mali; Koraro, Ethiopia; and Potou, Senegal) were selected to illustrate the site-specific activities and achievements in increasing basic food production and other related interventions. Together they constitute 55 out of the 80 Millennium Villages, with approximately 52,000 farming households and 310,000 people.

The general characteristics of the sites are presented in Table 1 and summarized below to illustrate the range in conditions in which the MVP is targeting MDG 1. The number of households within the different clusters ranges from less than 1000 in the case of Pampaida, to almost 13,000 in Sauri and Koraro (Table 2).

2.1. Geography, ecology, climate, and soils

The eight sites cover a range of agroecological zones: humid, subhumid, dry subhumid, semiarid, and arid tropics. They include tropical rainforest margins (Bonsaaso); dry subhumid Sudan savanna (Pampaida); Sahel (Tiby); coastal Sahara margin (Potou); maize-based bimodal systems (Sauri); maize-based unimodal systems in Miombo Woodlands (Mbola); maize-based unimodal, with small farms (Mwandama), and semiarid highlands with mixed crop-livestock (Koraro). Mean annual rainfall ranges from 270 mm in Potou to 1800 mm in Sauri. Most sites have unimodal rainfall patterns except for Sauri and Bonsaaso, with two rainy seasons where cropping is possible. Landscapes vary from lowlands in West Africa, including a coastal

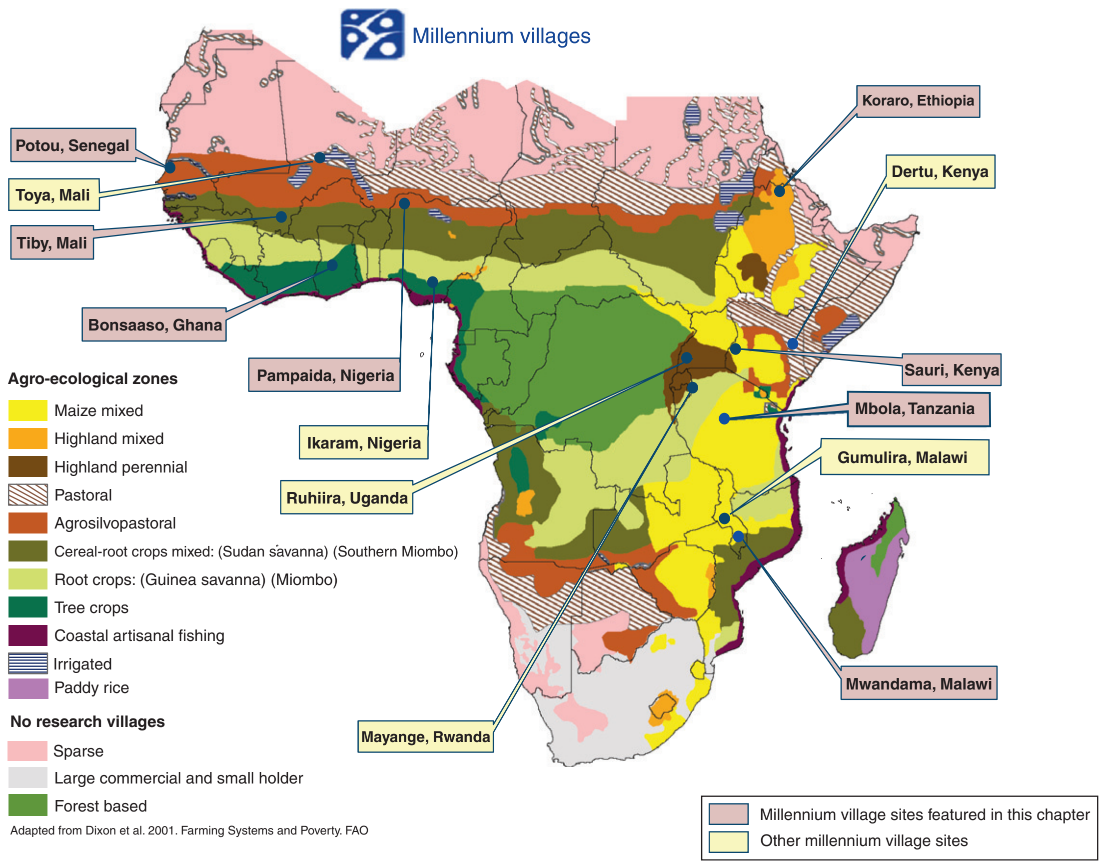

Figure 1 Location of Millennium Villages in sub-Saharan Africa. Adapted from Dixon *et al*. (2001).

Table 1 Site characteristics, arranged in decreasing order of annual rainfall

Village cluster, location	Farming system and AEZ[a]	Elevation (m)	Rainfall pattern and annual average (mm)	Length of major rainy season	Dominant soils	Population density (people per square kilometer)	Major crops[b]
Sauri, Nyanza Province, Kenya	Maize mixed, Subhumid tropical	1400	Bimodal 1800	March–August	Rhodic Hapludox, clayey	690	Maize, beans
Bonsaaso, Ashanti Region, Ghana	Tree crops, humid tropical forest	210	Bimodal, 1333	April–July	Hapludult, sandy loam	63	Cocoa, plantain, maize
Mwandama, Southern region, Malawi	Cereal root-crops mixed, subhumid tropical	900–1200	Unimodal, 1139	November –April	Rhodustalfs, loamy to clayey	724	Maize
Pampaida, Kaduna State, Nigeria	Agrosilvopastoral, dry subhumid	615	Unimodal, 1050	June–November	Haplustalfs, sandy to loamy	138	Sorghum, maize
Mbola, Tabora region, Tanzania	Maize mixed, dry subhumid	1050	Unimodal, 928	November–April	Haplustalfs, sandy	40	Maize
Tiby, Segou region, Mali	Cereal root-crops mixed, semiarid	275	Unimodal, 543	July–September	structurally inert sandy Ustalfs	98	Millet, cowpea, flooded rice
Koraro, Tigray region, Ethiopia	Highland mixed, semiarid	1550–2000	Unimodal, 500	June–August	Calciustepts, sandy	63	Teff, sorghum, maize
Potou, Louga region, Senegal	Arid (pre-Saharan), coastal artesian fishing	1–30	Unimodal, 270	July–October	Torripsamments (Niayes zone), sandy Haplustalfs (Diéri zone)	122	Onion, millet, groundnut

[a] Agrocolological zone (Dixon *et al.*, 2001).
[b] Grown by at least 50% of the households.

Table 2 Selected characteristics of farming households in baseline study prior to start of the project

Village cluster	Number of households	Average number of persons per household	Average area cropped per household (ha)	% of households using fertilizer	Fertilizer N rate (kg N ha^{-1})	Fertilizer P rate (kg P ha^{-1})	% of households using improved seed
Sauri	12,756	5.7	0.6	40	< 10	≤ 5	2
Bonsaaso	4,164	5.2	4.9	0	< 10	≤ 5	0
Mwandama	7,000	4	1.0	30	< 30	≤ 5	20
Pampaida	952	6	3.4	77	< 30	≤ 5	2.3
Mbola	6,610	5.6	3.4	39	< 10	≤ 5	Nd[a]
Tiby	5,300	12.6	9.6	21	< 30	≤ 5	80
Koraro	12,632	4.4	1.9	79	< 10	< 15	2.7
Potou	2,245	9.7	1.4	90	103[b]	< 15	90

[a] Not determined.
[b] The rate is for the Niayes zone where vegetables are produced as cash crops and therefore benefiting from high fertilizers. The rate is much lower in the Diéri zone where millet, groundnut, and cowpea are grown.

desert site, and highland sites up to 2000 m in East Africa. Soil types vary from sandy Entisols and Inceptisols in Potou and Koraro, Vertisols also in Koraro, to structurally inert sandy Alfisols subject to surface sealing in Tiby, sandy Alfisols in Pampaida, humid tropical Ultisols in Bonsaaso, red loamy to clayey Alfisols in Mwandama, and clayey Oxisols in Sauri.

2.2. Farming systems and crops

The farming systems vary from tree crops in the humid tropical forest zone in Bonsaaso, to mixed maize farming in Sauri, Mbola, Mwandama, highland mixed systems in Koraro, agropastoral systems in Pampaida and Tiby, and coastal irrigated desert in Potou. Farmers of Sauri, Mwandama, Pampaida, Mbola, and Koraro produce most of their food from cereal crops that have distinct planting and harvesting seasons. Maize (*Zea mays*) constitutes the major staple crop in Sauri, Mbola, and Mwandama. Pampaida is dominated by sorghum (*Sorghum bicolor*) and livestock in the nomadic Fulani zone, but maize and upland rice (*Oryza sativa*) are also important. The major staple crop in Koraro is teff (*Eragrotis tef*), but a variety of cereals, finger millet (*Eleusina coracana*), sorghum, wheat (*Triticum aestivum)*, barley (*Hordeum vulgare*), and maize are widely grown along with several grain legumes such as lentil (*Lens esculenta*). Cassava (*Manihot esculenta*) and sweet potatoes (*Ipomoea batatas*) are grown in all but the two driest clusters.

The three remaining sites have farming activities that occur at different times of the year. Potou comprises two zones, a coastal *Niayes* zone where fishing and irrigated onion (*Allium cepa*) production are the main activities conducted throughout the year, and a rainfed zone *(Diéri)* where pearl millet *(Pennisetum glaucum*), groundnut (*Arachis hypogaea*), and cowpea (*Vigna unguiculata*) are grown during a short rainy season. Bonsaaso relies primarily on a system of slash and burn where a few years of annual crops are followed by tree-based agroforests, composed mainly of cacao (*Theobroma cacao*). Tiby has about half of its area in a large irrigated rice scheme, while the upland areas are planted to millet and cowpeas in the rainy season and to small-scale irrigated vegetable gardens.

Cattle are important in all but two sites: in humid tropical Bonsaaso the presence of the tse-tse fly zone limits livestock to small ruminants; and the small farm sizes in Mwandama preclude grazing or forage production, with very few cattle and goats present. Some form of agroforestry, although not dominant is present at all sites. These include improved fallows, tree hedges for livestock feed, as well as fuelwood, timber, and fruit trees.

2.3. Farming households

The population density of the sites varies from 40 persons per square kilometer in Mbola to about 700 persons per square kilometer in both Sauri and Mwandama (Table 1). Baseline surveys, conducted prior to the interventions, indicate that the average size of household ranges from four persons in Mwandama to 13 persons in Tiby (Table 2). The average area cropped per household varies from about 0.6 ha in densely populated Sauri to 5 ha or more in less-populated sites, such as Bonsaaso, Tiby, and Potou's upland part. Typical of the African context, the use of mineral fertilizer and improved seeds is low in all sites. The percentage of farmers using any mineral fertilizer was below 50% in five sites, with no use of fertilizer in Bonsaaso. In all sites, including those where the majority of households use fertilizers, the rate of nutrient application was very low, often less than 10 kg N ha^{-1} and 5 kg P ha^{-1} per crop. Most households apply whatever limited quantities of animal manure and compost they can collect. While more than 50% of households used improved seeds in Tiby and Potou, less than 3% of households used improved seeds in the other sites.

3. Methodology

3.1. Decision-making

Community participation in identifying the problems with agricultural production, assessing possible solutions, developing plans and budgets, and then the subsequent implementation and monitoring is essential; first to achieve ownership and second to assure that the plans are appropriate and localized for the specific site (UNDP, 2007). Village leaders formed agriculture committees through community elections or appointments, or existing committees were strengthened. Efforts were made to assure representation from throughout the villages and to include underrepresented groups, specifically women and young people. These committees together with the project staff made the decisions. Project staff ensured that such decisions were science-based.

3.2. Agricultural interventions

In order to increase staple crop productivity basically from 1 to 3 t ha^{-1} of cereal yields, the villagers and project staff decided on the following interventions for the first two years:

- Reversing soil fertility depletion with subsidized mineral fertilizers.
- Providing improved seeds, also subsidized, either hybrids or open-pollinated cultivars, of the basic food crops recommended by national agricultural research institutes and Consultative Group in International Agricultural Research (CGIAR) offices in the various countries.
- Empowering agricultural extension officers with transportation and laptop computers, in order for them to train farmers in the latest knowledge

of good agronomic practices, including early planting, spacing, seed and fertilizer placement, harvest and storage methods, small-scale water management, and others.
- Farmers agreeing to contribute part of their harvest to the village school feeding programs.
- Constructing grain storage facilities to minimize postharvest losses as well as to store crop surpluses in order to sell later at higher prices, rather than immediately after harvest when prices are lowest.

After the first 2 years, the following additional interventions were added to trigger the transition from subsistence farming to diversified agriculture for improved nutrition and income generation:

- Promoting enterprise diversification, including high-value crops such as vegetables, fruits, spices, as well as dairy cows and goats, poultry, beekeeping, mushroom production, aquaculture, and various agroforestry systems.
- Promoting small-scale water management using treadle pumps, drip irrigation, and rainwater harvesting, for supplemental irrigation of high-value cash crops and dry-season farming.
- Improving nutritional security, including school-based nutrition programs such as locally produced school meals; introduction and demonstrations of the value of nutritious foods including orange-fleshed sweet potatoes, milk, soybeans, African leafy green vegetables, and fruits.
- Beginning the transformation to small-scale entrepreneurship: working with existing or new farmer associations; marketing studies to identify local demand for different high-value products; training on banking, credit and business accounting; establishing linkages to financial services for credit for farm inputs and bank accounts for savings; agroprocessing for adding value; use of cell phones for obtaining price information; and linking villagers to the value chain; and to markets starting with local, regional, and even international.
- Risk reduction via improved weather forecasting and crop insurance.

Improved germplasm as well as several agronomic practices used at each of the clusters (Table 3) were those recommended by research and extension agencies, since no adaptive research was done at the villages, following the philosophy of using knowledge already available. In this chapter, emphasis is given to one major rainfed crop per site, although a brief discussion on irrigated crops is also provided for sites where they constitute the primary farming activities.

3.2.1. Improved germplasm

Maize is the major crop of Sauri, Mwandama, and Mbola. Maize was also promoted for diet diversification in Pampaida and Bonsaaso. In Pampaida, soybean and upland rice were also promoted, but at a lower scale.

Table 3 Management applied during cropping seasons in various village clusters

Village, cluster	Crop	Cultivars, variety or hybrid	Method of land pre paration	Planting fertilizer	Topdressing fertilizers and application time	N rate (kg N ha^{-1})	P rate (kg P ha^{-1})	Plant spacing (cm)	Weeding	Major pests
Sauri	Maize	WS 502, WS 505, WS 402, DK 8031	Hand hoeing, flat	DAP, point placement	Urea, at knee height	80	25	75 × 30	Two times	Stem borer, streak virus, striga
Bonsaaso	Maize	Obatanpa, Golden Jubilee	Hand hoeing, ridging	NPK[a] point placement	$(NH_4)_2SO_4$ at knee height	45	8	80 × 40	Three times	Stem borers
Mwandama	Maize	DKC 8073, DKC 8033	Hand hoeing, tied ridging	NPS point placement	Urea, at knee height	86	11	75 × 25	Three times	Stem borer, streak virus, wire worms
Pampaida	Maize	Oba Supa 1, JO-2, Oba 98	Animal traction, ridging	NPK[a] point placement	Urea, at knee height	129	26	75 × 25	Three times	Stem borer, streak virus, striga
Mbola	Maize	SEEDCO, Pannar 67 DK8031 DK8053	Hand hoe, ridging	DAP or PR[b] point placement	Urea, at knee height	80	25	90 × 25	Two times	Stem borer, streak virus, striga
Tiby	Millet	Toronio	Animal traction, ridging	NPK[a] broadcast	Urea, at 3 weeks	53	13	50 × 50	Two–three times	Mildew, Acarien
Koraro	Teff	DZ-CR-27, DZ-01-947	Animal traction flat	DAP, broadcast	Urea, at 3 weeks	41	20	broadcast	One–two time	Stem borers, shoot fly, white grub
Potou	Groundnut	55, 437	Animal traction flat	NPK[a], PR[b], broadcast	none	3	28	50 × 12	Three times	Locusts

[a] NPK basal fertilizers have different formulations (N, P_2O_5, K_2O) as follows: 23–21–10 in Bonsaaso, 15–15–15 in Pampaida and Tiby, and 6–20–10 in Potou.
[b] Phosphate rock. Minjingu Phosphate rock replaced DAP (diammonium phosphate) in the third year in Mbola, whereas phosphate rock was used in each season in Potou.

In Bonsaaso, cowpea was introduced because the prevailing farming system included few protein sources. Interventions on cacao in Bonsaaso focused on improving the current agronomic practices to increase production and reduce pest and diseases. In Tiby, millet and flooded rice were the two crops targeted. In Koraro, interventions targeted various cereals, whereas pulse crops such as chickpea (*Cicer arietinum*) were introduced. For the drier, rainfed zone of Potou, the project focused initially on improved seeds of millet but switched to groundnut and cowpea in subsequent years.

Most of the maize germplasm used were hybrids, except for Golden Jubilee and Obatanpa in Bonsaaso (Table 3). Germplasm of the other crops were all improved varieties.

3.2.2. Land preparation

Land preparation followed the traditional practice of hand hoeing in most clusters in humid and subhumid zones. In drier zones (Tiby, Potou, Pampaida, and Koraro), animal traction is practiced (Table 3). In Bonsaaso, Mwandama, Pampaida, and Mbola crops were grown on ridges, whereas flat planting was practiced in Sauri, and Potou. Spacing between ridges was reduced. There was no mechanization and reduced tillage was not practiced.

3.2.3. Plant spacing

The spacing of 75 cm × 25 cm and with one plant per hole was practiced in Pampaida and Mwandama because it is promoted by Sasakawa Global 2000 in those countries (Table 3). This is in contrast with the traditional plant spacing of 90 cm × 90 cm with four seeds planted per hole in Mwandama, which is considered too wide. Within a cluster, various spacing recommendations prevailed depending on whether the crop was grown in monoculture or intercropped with other crops like groundnuts, common beans (*Phaseolus vulgaris*), cowpeas, pigeon pea (*Cajanus cajan*), or cassava. Also it depended on rainfall pattern; for example, maize in Sauri is planted at 75 cm × 30 cm spacing for monocrop in the wetter areas but 90 cm × 30 cm is recommended for drier parts of the cluster.

3.2.4. Fertilizer use

The sources of mineral fertilizers, their placement, and rates of application also varied among clusters, depending on their availability and the recommendations from the national research and extension services (Table 3). Diammonium phosphate (DAP) is used as the source of nitrogen and phosphorus for basal applications, and urea for top-dressing in most East African sites. The exception is Malawi, where the planting fertilizers is a unique blend (23 N-21 P_2O_5-0 K and 4 S) especially imported by the government. Compound NPK fertilizers are used in the most West African sites for basal application, and either urea or ammonium sulfate is used for top-dressing.

The placement of the basal fertilizer applications is Africa's version of precision farming. Farmers dig a planting hole at the recommended spacing, calibrate the applied fertilizer with soda bottle caps, cover it, and plant the seeds. The exceptions are in the three driest sites, Tiby, Koraro, and Potou, where basal fertilizer applications were broadcast and incorporated at tillage.

Rates of nitrogen application for maize ranged from 45 to 129 kg N ha^{-1} per crop, while that of phosphorus was 11 to 28 kg P ha^{-1}. The rates of nitrogen applied, except for the highest rate applied in Pampaida, Nigeria, are below those recommended to obtaining maximum yields.

3.2.5. Pest management

No herbicides were used. Two weedings were done for the staple crops in all sites, except for Koraro. The major pest for maize at all sites was the stem borer (*Busseola fusca*) and maize streak virus was the major disease (Table 3). Striga (*Striga hermonthica*) infestations occurred in Sauri, Pampaida, and Mbola. No insecticides for controlling stem borers were used, except in a few cases in Mbola. The pests and disease attacks did not result in crop failure in any site except for the locust invasion in Potou during the first season.

3.2.6. Irrigated crops

In addition to rainfed crops, rice and onions are major irrigated crops in Tiby and Potou, respectively. In Tiby, irrigated rice is grown on half of the cluster's cropland, and has been supported by the project with inputs. However, the current irrigation scheme requires much improvement in irrigation water control, and land leveling.

In Potou, onion is produced in the coastal zone. The MVP provided improved seeds and a change in irrigation practice. Previously, most of the onion fields were irrigated with buckets from the site's numerous concrete-lined, shallow wells. The watering rate was 10 l m^{-2} day^{-1} done in the middle of the day, when irrigation is least efficient. Consequently, the shallow water table was dropping at an alarming rate of 20 cm $year^{-1}$, resulting in a high risk of salt intrusion from the Atlantic Ocean. This changed to drip irrigation with a diesel pump using the same wells. One pump can irrigate 0.5 ha day^{-1}, in 12–36 min with drip irrigation.

3.2.7. Grain banks and storage facilities

With the anticipated increases in crop yields, storage facilities were organized in advance of surplus harvests. These facilities helped to reduce postharvest losses and also provide an option for farmers so that they do not have to sell their surplus immediately after harvest when prices are generally low. Community-owned storage facilities were constructed or improved in the second year of the project. The community contributed to the construction by making bricks, bringing stones, sand, poles, and labor for building the facility, whereas the project contributed cement, roofing materials, metal doors and windows, and skilled masons.

3.2.8. Subsidy and distribution of fertilizers and improved seed

The entry point for improving crop production was to provide support of subsidized improved seeds and mineral fertilizers at recommended rates to farmers. Seeds, once they were identified, were purchased from local seed companies operating in the country or region. In some cases, they were donated by international seed companies, but only if they were the recommended varieties. Fertilizers were also purchased from dealers in the region, or received as donations from partners or through government input support programs in the case of Mwandama and Potou.

The subsidy rates and how they were implemented also varied among sites; subsidies were initially high ranging from 50 to 100% of the market costs and then gradually decreased in the next 2–3 years with the expectation that farmers would eventually be able to purchase the inputs from credit, based on sales of their increased crop production. The MVP made contracts or distributed vouchers to each farmer stating the conditions of the subsidy. In most sites, farmers were required to pay back a percentage of their harvest in grain to the school meals program; in other sites, harvest payments went into community-run grain banks, where the crop was sold either to support the school meals program or to generate a revolving fund for purchasing seeds and fertilizers in subsequent years.

All farming households were eligible to receive the subsidized inputs. The agricultural committees distributed the inputs to all farmers with oversight from agriculture extension officers and village facilitators. Each farmer signed a contract acknowledging the receipt of inputs, certifying that the inputs would be used on their fields, and committing to the partial in-kind repayment, generally 100–300 kg of grain per household. The agriculture committees were also responsible for collecting the repayments.

3.2.9. Training

Farmers were introduced to and trained in improved inputs and agronomic practices through a variety of methods throughout the cropping season. As a first step, discussions were held with agriculture extension officers to assess if they were up-to-date on information and recommendations on improved cultivars, fertilizer use, integrated soil fertility management, and other agricultural techniques; they were provided with refresher training and information sessions as needed. Farmer training sessions were initiated prior to the beginning of key activities. In these sessions, agricultural extension agents and MVP agriculture facilitators taught groups of about 100 farmers. The first sessions focused on land preparation, fertilizer placement, plant spacing, and specifics regarding improved seeds including their advantages over local seeds. Although the use of improved seeds was promoted, farmers were still encouraged to keep plots of their traditional seeds. Subsequent training sessions were conducted just before the start of major activities such as application of top-dressing fertilizers, harvesting, and postharvest management. Each of the training sessions consisted of a short lecture session, followed by practical activities that included land preparation and planting, visits to demonstration plots for best practices, farmer field schools, exchange visits between villages, and visits outside the project area to learn from successful interventions.

3.3. Data collection and analysis

3.3.1. Crop yields

At the end of each growing season, yields were measured in a minimum of 30 households per village cluster in plots where improved germplasm and fertilizers were applied. The households were selected randomly from households that had been surveyed for the broader socioeconomic surveys (Sanchez *et al.*, 2007) and represented the geographic and socioeconomic range of households for the sites. Yield estimations were made in 3–6 quadrants placed randomly in each plot, at least 3 m away from the borders. The quadrants size ranged from 9 to 25 m^2, depending on the site. All plants in each of the quadrants were harvested, the fresh weights measured and subsamples of grain taken for dry weight measurements. Grain yields are expressed at 14% moisture content. A team of enumerators, members of the agriculture committee, and farmers participated in measuring the yields.

Efforts were also made to collect yield data in randomly selected nonintervention plots to serve as controls. Ideally these controls would be located in villages neighboring the cluster, but this type of sampling was possible only in Mwandama and Koraro. In other clusters, it was difficult to obtain permission from farmers outside the MVP area to take yield estimates. In these sites, yield estimates for controls were taken from plots within the MVP area but where inputs were not applied. This type of sampling may underestimate or overestimate actual nonintervention controls. Underestimates of control yields would result if farmers selectively chose their better fields to apply the improved seed and fertilizer inputs and the plots where control yields were estimates were on poorer quality soils. Control yields would be overestimated within the MVP area because farmers had been exposed to training on improved agronomic practices and may have applied these practices to these plots, and therefore such controls do not accurately represent what farmers would have done if they were not participating in the project.

Analyses of data were performed using Stata 10 (Hamilton, 2009). Yield data were analyzed by grouping them into four yield quartile groups. Quartiles refer to the 25th, 50th, or 75th percentiles of a frequency distribution divided into four parts, each containing a quarter of the sampled households. Quartile 1 represents the group with the lowest yields, and quartile 4 the highest yields, whereas quartile 2 and quartile 3 represent the middle groups between the 25th and 75th percentiles. For sites with bimodal rainfall pattern, only yields during the major season are reported.

3.3.2. Daily caloric requirements

Minimum per person grain yields needed to meet basic caloric requirements were estimated by the amount of grain needed to provide 2100 calories per day per person (Latham, 1997). These requirements are equivalent to 219 kg of maize per person per year and 209 kg of teff per person for the case of Koraro. The annual crop production for a household to produce the targeted amount of grain was estimated based on the average number of people per household for each site (Table 2). The area required per household to produce that minimum amount of grain was then calculated based on the yields obtained in each quartile.

3.3.3. Value-to-cost ratios

Increasing crop production in itself is important for addressing hunger; however, the ability of farmers to continue achieving such yields depends on the profitability of the crop and the farmers' ability to save and reinvest in agricultural inputs or other income generating activities. In order to assess this potential, the value-to-cost ratios were calculated for the staple crops for each season and cluster. To make these calculations, prices were collected for:

- Costs of fertilizers and seeds for each cropping season at actual, *not subsidized,* local market prices.
- Farm gate crop prices at harvest time, when prices are generally lowest.
- Peak prices occurring later in the year, when the surplus crop was actually sold.

Prices were collected in local currencies and converted to US dollars at the prevailing exchange rates. The unsubsidized input costs and the crop peak prices were used to calculate the value-to-cost ratio as a first indicator of acceptability of investment, using the following formula:

$$V/C = \frac{(Y - Y_c)}{X}$$

where Y (\$) is the value of the crop in intervention plots, Y_c (\$) is the value of the crop harvested in control plots, and X (\$) is the cost of inputs (seeds and fertilizers).

The cost of producing each extra ton of maize above that produced in the control was also calculated.

4. Results

4.1. Crop yields

For all the Millennium Village clusters growing maize (Sauri, Bonsaaso, Mwandama, Pampaida, and Mbola), average maize yields overall were 4.4 t ha^{-1} ranging from 5.1 t ha^{-1} in Sauri to 3.5 t ha^{-1} in Pampaida (Table 4). Seasonal average maize yields per village cluster were at least 3.2 t ha^{-1}. The initial MVP package of agricultural interventions resulted in at least a doubling of maize yields in Sauri, Mwandama, Mbola, and Pampaida, and teff yields in Koraro, when compared to preintervention yields. Maize yields in Bonsaaso, Ghana were not as responsive but the preintervention and control yields were relatively high. Yields compared to controls were not doubled in Sauri and Pampaida; for the case of Sauri, there are questions about the high control yields obtained based on other data on crop yields with low inputs from the area (Jama and Kiwia, 2009; Nziguheba *et al.*, 2002a) but for Pampaida, the reasons for relatively low maize yields are unclear.

In contrast to the success in doubling yields for maize and teff, there was little improvement in millet yields in Tiby and Potou, and groundnut yields in Potou. Both of these village clusters are in the semiarid to arid zones where rainfall amounts and patterns often result in crop failures.

4.1.1. Interannual yield variation

There were slight variations in yields between seasons within a cluster (Table 4, Fig. 2). The yield variations were due to a variety of climatic, cultural, and socioeconomic factors. In Sauri, the variations in maize yields in 2005 (Year 1), 2006, and 2008 are correlated with seasonal rainfall totals. But the lowest yields observed in 2007, the year with the highest seasonal rainfall, are perhaps due to a shift in the management of inputs distribution from the MVP to a local NGO and agro dealers. Some farmers could not readily access the inputs. Nevertheless, a village average of 4.4 t ha^{-1} is still above the target of 3 t ha^{-1}. In Mbola, the lowest yields observed in the 2006/2007 (year 1) cropping season were linked to low quality of maize seeds used that season and replanting was required in most fields; but also in this first year of the MVP, farmers were reticent to adopt the improved agronomic practices. Many farmers refused to increase the plant density from their normal practices with a result that the population density was low, about half of the 45,000 plants ha^{-1} that was recommended. Farmers did realize that those who followed the recommendation had very good harvests and in the following season, 2007/2008 (Year 2), the majority of farmers followed the recommended practices. Coupled with good rainfall, this resulted in a bumper harvest, averaging the highest yields of all, 5.9 t ha^{-1} with all farmers

Table 4 Average grain yields at baseline (preintervention) and those measured during years of MVP implementation in intervention and nonintervention (Control) plots; and the total rainfall during the cropping seasons

Village clusters	Intervention type	Yields (t ha^{-1})					
		Preintervention	Year 1	Year 2	Year 3	Year 4	Overall cluster average
Sauri	Yield MVP (t ha^{-1})		4.9 (1.6)[a]	5.7 (1.6)	4.4 (1.5)	5.2 (1.8)	5.1
Maize	Yield control (t ha^{-1})	1.9	Nd[b]	3.4 (1.0)	4.0 (0.9)	2.7 (0.7)	3.4
	Rainfall (mm)	734	729	1097	1111	918	
Bonsaaso	Yield MVP (t ha^{-1})		4.2 (1.0)	3.8 (1.1)	5.4 (1.0)	Tbd[c]	4.5
Maize	Yield control (t ha^{-1})	2.2	2.3 (0.8)	2.6 (0.8)	3.6 (0.9)	Tbd	2.8
	Rainfall (mm)	615	753	647	731	Tbd	
Mwandama	Yield MVP (t ha^{-1})		5.2 (1.7)	4.0 (1.3)	4.3 (1.6)	4.7 (1.2)	4.5
	Yield control (t ha^{-1})	0.8	2.2 (0.9)	1.6 (0.6)	1.6 (0.7)	1.5 (0.8)	1.8
Maize	Rainfall (mm)	780	1163	450	992	961	
Pampaida	Yield MVP (t ha^{-1})		3.2 (0.4)	3.7 (0.7)	3.5 (1.1)	Tbd	3.5
Maize	Yield control (t ha^{-1})	0.8	1.8 (0.5)	2.0 (0.3)	2.5 (0.6)	Tbd	2.1
	Rainfall (mm)	687	884	863	972	Tbd	
Mbola	Yield MVP (t ha^{-1})		3.3 (1.0)	5.9 (1.5)	4.1 (1.3)	Tbd	4.4
	Yield control (t ha^{-1})	1.0	1.7 (0.5)	0.9 (0.4)	1.9 (1.5)	Tbd	1.3
Maize	Rainfall (mm)	519	720	758	561	Tbd	
Tiby	Yield MVP (t ha^{-1})		1.1 (0.5)	1.6 (0.6)	1.2 (0.4)	Tbd	1.4
	Yield control (t ha^{-1})	0.8	0.8 (0.5)	1.4 (0.6)	Nd	Tbd	1.1
Millet	Rainfall (mm)		592	437	545	Tbd	
Koraro	Yield MVP (t ha^{-1})		Nd	1.4 (0.5)	1.5 (0.5)	1.2 (0.4)	1.4
	Yield control (t ha^{-1})	0.6	Nd	0.6 (0.2)	0.8 (0.3)	0.7 (0.3)	0.7
Teff	Rainfall (mm)	446	Nd	515	618	268	
Potou	Yield MVP (t ha^{-1})		Nd	0.8 (0.04)	0.7 (0.02)	Tbd	0.8
	Yield control (t ha^{-1})	0.5	Nd	0.6 (0.02)	0.6 (0.01)	Tbd	0.6
Groundnut	Rainfall (mm)	350	278	217	309	Tbd	

[a] Numbers in parentheses are standard deviation.
[b] Not determined.
[c] To be determined.

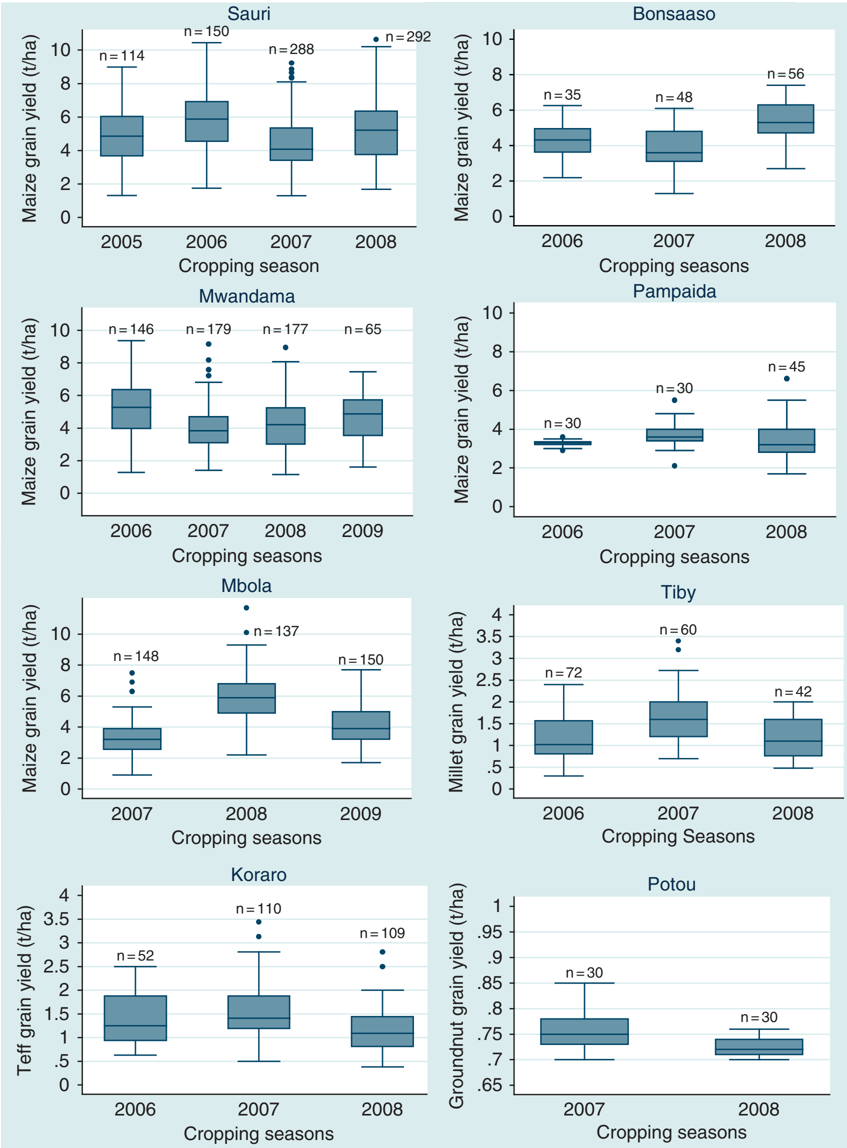

Figure 2 Trend and distribution of grain yields obtained during various cropping seasons with MVP interventions in selected Millennium Villages clusters. Boxes indicate yield ranges in the 25–75% yield quartiles. Bars indicate the limit of the nonoutlier minimum and the nonoutlier maximum. *n* is the number of sampled plots per season.

achieving more than 2 t ha^{-1} (Fig. 2). The decrease of yield in 2008/2009 (Year 3) cropping was due mainly to low seasonal rainfall but also to low adaptability of farmers to the switch from DAP fertilizer to Minjingu phosphate rock plus urea as the basal application.

In Tiby, where millet was the first crop targeted, only a slight increase of 37% was observed compared to preintervention levels and control plots (Table 4). Due to the general low productivity of millet, its vulnerability to weather fluctuations, and the low cost of the millet seed, which farmers were able to pay on their own, farmers preferred to support higher value crops, such as irrigated rice and vegetables in subsequent seasons. Therefore, from 2008 (Year 3) onward, the support for millet was limited to agronomic management but not inputs and there was a 25% decrease in millet yields compared to yields in 2007 (Fig. 2).

Although teff is a major staple crop grown by all households in Koraro, various other cereals are grown along with teff, and also benefited from the project interventions. For reason of simplicity, the discussion will focus on teff. The average teff yield in the year before intervention was similar to yields measured in the control villages during three consecutive years of intervention (Table 4). In 2006 (Year 2), teff yields doubled in intervention plots compared to yields in control villages. Yield variations in 2007 and 2008 follow rainfall patterns; in particular, in 2008, there was a long dry spell occurring during the cropping season, which was severe in some parts of the cluster.

In Potou, long dry spells and many insects, including locust invasions that caused significant damage to millet characterized the first year of interventions. The poor rainfall during this season left farmers unmotivated to support millet. Farmers preferred to support groundnut and cowpea seeds because of their higher costs compared to millet seeds. As a result, the area under millet increased during the first year of intervention from 1186 to 1514 ha, and then decreased drastically to 659 ha in the 2008 cropping season. Groundnuts were supported in the second year of the project. Low yields of groundnuts with only 15–25% increases over the control yields, were obtained during the 2 years of input support (Table 4, Fig. 2) and were attributed to low rainfall in this marginal area. Despite these low improvements in yields, farmers value groundnuts as cash crop, and with project support, the area under groundnut increased from 3157 ha in 2005 (before project) to 4251 ha in 2008. Beside the grain, groundnut stover is utilized by farmers as livestock feed.

4.1.2. Household yield variation

Though average maize yields doubled or even tripled across the sites compared to preintervention, there was considerable variation and range in yields among the farms within sites even though all households had access to the project inputs (Fig. 2). In general, 75% or more of the farm plots sampled had maize yields of 3 t ha^{-1} except for Mbola in 2007 and Pampaida in 2008.

Most sites, however, also had a few households with yields below 2 t ha^{-1} in most seasons; such yields are similar to or even below the average yield from the control plots in those sites. Usually, less than 10% of the households had yields less than 2 t ha^{-1}.

On the other extreme, in all village clusters and all seasons, households in the highest quartile reached yields of 6 t ha^{-1}, with the exception of Mbola in 2007 and Pampaida in any season. Yields in Pampaida never reached 6 t ha^{-1}.

There was also a large variation in teff yields range between seasons in Koraro. In 2006, 32% of sampled households had yields below 1 t ha^{-1}. The value reduced to 17% in 2007 when yields in the second quartile were above 1 t ha^{-1}, while they increased to 42% in 2008. The distribution of yields in quartiles 2 and 3 was wide in 2006 whereas it narrowed in 2008 when all yields in these quartiles were below 1.5 t ha^{-1} (Fig. 2).

4.1.3. Meeting caloric requirements

For all maize growing sites, the annual quantity of maize required for a household to satisfy its caloric needs ranged between 0.9 and 1.3 t (Table 5). An indicator for measuring progress toward the hunger MDG is the percentage of the population below the minimum dietary energy intake level (Palma *et al.*, 2009). Producing the basic caloric requirements for households was essentially not possible on the small farm sizes in Mwandama and Sauri (1.0 and 0.6 ha, respectively) at baseline yields (Table 2, Table 5). The farm size is big enough in the other sites growing maize, but in sites requiring more than 1 ha to produce the basic amount of maize, labor may become a constraint to production. The increased yields with project interventions reduced the area required to produce the basic caloric requirement to only 20–40% of that required at baseline yield levels. Even for farmers in the lowest quartile of yield production, average farm sizes were sufficient (Table 2, Table 5). The only situation for which insufficient maize would be produced with seed and fertilizer to meet this basic requirement is in the lowest farm size quartile in Sauri, which averaged only 0.14 ha. Households with such small farm size cannot meet the caloric needs even if they are able to produce the yields of the highest quartile. Such households, often headed by elderly widows have to depend on social safety nets.

In Koraro, the amount of teff required for a household to satisfy its basic caloric needs was estimated to be 0.92 t. This would require an area of 1.5 ha. While the average farm size, 1.9 ha is sufficient to meet this requirement, many other crops are grown in Koraro. Project interventions reduced the required area to less than half using the average yields attained.

4.2. Value-to-cost ratios

The investment in inputs proved to be profitable, provided the surplus yields were stored and sold when the value of the crop was at peak prices. Profitability is defined when the value-to-cost ratios are 2 or higher (Morris *et al.*, 2007).

Table 5 Annual amount of maize or teff required for a household to meet the minimum caloric needs and the area required to produce that amount, calculated based on various level of crop production

Village clusters	Maize or teff needed to meet caloric requirement per household (t)	Area required to produce sufficient grains for household basic caloric requirement (ha)			
		Based on preintervention yields (Baseline)	Based on Average intervention yields	Based on the lowest yield quartile	Based on the highest yield quartile
Sauri	1.2	0.6	0.24	0.4	0.17
Bonsaaso	1.1	0.5	0.24	0.4	0.20
Mwandama	0.9	1.1	0.19	0.3	0.13
Pampaida	1.3	1.6	0.37	0.5	0.29
Mbola	1.2	1.2	0.27	0.4	0.20
Koraro	0.9	1.5	0.66	1.2	0.47

The cost of inputs rose slightly between the first year of the project and 2007 in all sites but escalated sharply in 2008 (corresponding to Year 4 in Sauri, Mwandama, and Koraro, and to Year 3 in others) following large hikes in food and fertilizer prices (ODI, 2008). For all sites, seed and fertilizer prices of the 2008 planting almost doubled. In Mbola, the price of DAP in 2008 rose to \$1638 t^{-1} compared to \$830 t^{-1} in 2007 and nearly quadrupled compared to the first season prices (\$274 t^{-1}). The decrease in the input costs in Mbola in Year 3 harvest was due to switch from the most expensive P fertilizer (DAP) to Minjingu phosphate rock, which was cheaper (\$642 t^{-1}) but has been proved to be an effective source of phosphorus (Szilas *et al.*, 2008).

In terms of profitability, the prices of maize and other crops also increased to partially offset the rise in fertilizer prices. For example, the price of maize in Sauri at harvest time rose from \$120 t^{-1} in Year 1 to \$154 t^{-1} in Year 2 and to \$196 t^{-1} in Year 3. But in Year 3, the overall value of the harvested maize decreased compared to the Year 2 value because of lower yields in Year 3; this drop occurred even though the price of maize increased (Tables 4 and 6).

Peak prices for the crop usually occurred 6–9 months after harvest, at the time when farmers are preparing for the following season. As expected, selling the product several months after harvest generated higher values than selling at harvest time. The magnitudes of the difference between low and peak prices varied between sites and seasons. For example, the value of the maize at peak price was at least double the value of harvest in Pampaida; whereas, only a slight increase of up to 45% was observed for maize in Bonsaaso and millet in Tiby. There was a general increase in the value of both the harvest and peak prices in 2008 compared to other seasons as a result of the general global hike in prices of food commodities observed during that year.

A major challenge in selling surplus crop has been to find buyers for crops grown in remote areas, where markets and buyers are generally not organized. For example, in Koraro and Bonsaaso which are located far from large towns (Makelle and Kumasi, respectively), farmers were organized to sell their agriculture products in bulk and the project facilitated the acquisition of trucks to transport products to the markets; communities were trained to manage the trucks and after an initial period of subsidy, the trucks were to be maintained and run by the community. Various types of buyers were identified for the sites: Tiby sells all its cereals at the annual cereal fair in Segou, the nearby regional capital; Sauri and other clusters sell to local millers, and some are selling to the World Food Program's Purchase for Progress project, where local foods are purchased for food aid in acutely hungry areas (Jurry, 2008).

The V/C ratios varied between sites and between seasons but were always higher for peak prices compared to harvest prices. The V/Cs at peak price were greater than 2 at all sites, except for millet in Tiby and groundnut in Potou and Year 3 in Sauri. For maize, the highest V/C was observed in Bonsaaso (Ghana) and was higher than 4 using both harvest and

Table 6 Input cost (seed and fertilizers), values of the harvest crop at harvest and peak prices, and the V/C ratios

MV site	Crop type	Category price	Values of harvested crop and cost of input ($ ha^{-1})				V/C			
			Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3	Year 4
Sauri	Maize	Input cost[a]	138	139	195	285				
		Harvest	589	879	857	1799	Nd	2.6	0.4	2.9
		Peak	1326	1689	1619	2270	Nd	5.0	0.8	3.7
		Cost per output ($ t^{-1})[b]	Nd[c]	60	488	144				
Bonsaaso	Maize	Input cost	82	106	159	Tbd[d]				
		Harvest	1599	1447	2917	Tbd	9.0	4.3	6.2	Tbd
		Peak	1599	1771	4243	Tbd	9.0	5.3	9.0	Tbd
		Cost per output ($ t^{-1})	43	88	88	Tbd				
Mwandama	Maize	Input cost	155	170	202	341				
		Harvest	351	285	463	797	1.3	1.0	1.4	1.6
		Peak	629	861	1214	1202	2.3	3.1	3.7	2.4
		Cost per output ($ t^{-1})	52	71	75	107				
Pampaida	Maize	Input cost	253	297	487	Tbd				
		Harvest	487	1805	1360	Tbd	0.8	2.8	0.8	Tbd
		Peak	3178	4547	2720	Tbd	5.5	7.2	1.6	Tbd
		Cost per output ($ t^{-1})	181	175	387	Tbd				
Mbola	Maize	Input cost	117	237	225	Tbd				
		Harvest	391	1143	744	Tbd	1.6	4.1	1.7	Tbd
		Peak	1005	2039	1370	Tbd	4.0	7.2	3.2	Tbd
		Cost per output ($ t^{-1})	73	47	102	Tbd				
Tiby	Millet	Input cost	127	135	245	Tbd				
		Harvest	145	296	290	Tbd	0.3	0.3	Nd	Tbd

(continued)

Table 6 (*continued*)

MV site	Crop type	Category price	Values of harvested crop and cost of input ($\$$ ha^{-1})				V/C			
		Peak	169	416	389	Tbd	0.4	0.5	Nd	Tbd
Koraro	Teff	Input cost	Nd	78	90	155				
		Harvest	Nd	609	856	1143	Nd	4.5	4.4	3.1
		Peak	Nd	814	1663	905	Nd	6.0	8.2	2.5
Potou	Groundnut	Input cost	Nd	250	215	Tbd				
		Harvest	Nd	825	771	Tbd	Nd	0.3	0.3	Tbd
		Peak	Nd	990	1113	Tbd	Nd	0.4	0.5	Tbd

[a] The cost of inputs (fertilizers and seeds) was calculated based on the actual local market prices, not on subsidized prices.
[b] Represents the cost of producing an extra ton of maize over the control yields by using fertilizers and improved seeds.
[c] Not determined.
[d] To be determined.

peak prices, and reached as high as 9 during peak prices. The input costs for Bonsaaso were lowest compared to other sites growing maize. The V/C was greater than 2 for two seasons in Sauri. The low V/C in Year 3 was due to high maize yields observed in the control plots, averaging 4 t ha^{-1}; in V/C calculation no input costs were included in the controls, which led to high value of maize produced at zero cost. As mentioned previously, the control yields for Sauri in all seasons are considered as overestimates so the V/C ratios are also probably underestimates. The V/C in Mwandama at harvest prices were always below 2. Despite yields twice that of control plots, the prices of maize were extremely low postharvest, resulting in low value of maize compared to values in any other MV sites. Storing maize and selling it at peak prices resulted in V/Cs greater than 2 all years in Mwandama. A similar scenario was observed in Year 1 and Year 3 in Mbola, and in Year 1 in Pampaida.

The use of inputs on millet in Tiby and groundnut in Potou had little effect on grain yields (Table 4) and resulted in unfavorable V/Cs of less than 1 (Table 6). As indicated earlier, input supports on millet were withdrawn in Tiby in 2008. In Potou, groundnut is an important cash crop for the rainfed zone and it was the top priority by the community for input support. Despite the low grain yields and low V/Cs, groundnut is viewed by the community as a very important crop because of its role as livestock feed. Groundnut stover yields are about twice that of grains, and are sold at a price of about 80% of that of the grains but V/Cs have not been calculated with the stover included as part of the sales.

In Potou, millet and cowpea are viewed by the community as subsistence crops whereas groundnut and onions are produced for selling; thus the farmers would not invest on inputs for the subsistence crops but rather put them on onion which is the major cash crop. Onion yields have increased from an average of 20 to 30 t ha^{-1} due to project interventions, and the area under onion expanded from 800 ha in 2006 to 1595 ha in 2008. The marketing of onions has improved due to an organized structure in credit union and to the ban of onion import during the period from March to August. This has lead to increased price of onion from \$145 t^{-1} in 2005 to \$310 t^{-1} resulting in V/C ratios above 4 (data not shown). The income from onion and groundnut are used to purchase food in case of poor performance of millet and cowpea.

Many African countries rely on imports to satisfy national food requirements. The cost of imported food is more than that for producing a similar amount within the country; stimulating local production and sourcing is a cheaper alternative to shipping food aid from the United States (estimated to \$806 t^{-1} in 2008) as indicated by the cost of producing a ton of maize in our study (Table 6) (Sanchez *et al.*, 2009; USAID, 2008). This alternative also can increase demand for local products and stimulate local agricultural development.

4.3. Crop and enterprise diversification

Crop diversification activities for the various village clusters started in the second year and now include off-season, or dry-season growing of vegetables (tomatoes, onions, cabbage, melons, and sweet corn) mostly on residual moisture in lowland areas or with drip irrigation; spices (chilies and ginger), and other rainfed crops (orange-fleshed sweet potatoes, tissue-cultured banana, groundnuts, sunflower, soybean, and hibiscus (locally known as *bissap* in Potou)(Table 7)). Livestock activities include support for dairy cattle, dairy and meat goats, poultry, including artificial insemination and veterinary services. Other activities outside the farmed fields were also developed, such as honey, mushroom, and aquaculture production.

Table 7 Selected diversification interventions for improving nutrition and income generation in various village clusters

Village name	Type of enterprise	Number of household involved	Area covered (ha)	Number of livestock heads
Sauri	OFSP[a]	429	53	Na
	Dairy goat	340	Na[b]	390
	Chicken	330	Na	4,800
Bonsaaso	Cowpea	440	88	Na
	Citrus	122	33	Na
Mwandama	Tomatoes	1,570	60	Na
	OFSP	200	20	Na
	Goats	162	Na	287
Pampaida	Goats	28	Na	56
	Soybean	544	300	Na
	Rice	567	450	Na
Mbola	OFSP	1,500	155	Na
	Sunflower	5,579	2,232	Na
	Chicken	700	Na	765
Tiby	Vegetables	2,960	42	Na
Koraro	Tomatoes	2,016	210	3,680
	Chilies	1,992	45	Na
	Chicken	736		
Potou	Onion	1,700	1,549	Na
	Bissap (Hibiscus)	2,633	399	Na
	Small ruminants	1,409[c]	Na	48,352

[a] Orange-fleshed sweet potatoes.
[b] Not applicable.
[c] Interventions consist of veterinary services.

5. Discussion and Way Forward

The results presented constitute evidence-based information on how to get Africa out of its 1 t ha^{-1} yield trap and move the African Green Revolution forward. We discuss the implications in terms of crop production, incorporating organic nutrient inputs, improved human nutrition, crop and enterprise diversification, subsidies and credit, climate risk and management, irrigation, safety nets, and the value of the integrated multisectorial approach.

5.1. Crop production

The initial successes of doubling maize yields and exceeding the overall "green revolution" yield target of 3 t ha^{-1} in the Millennium Villages confirm the importance of the four key simultaneous interventions; improved germplasm, subsidized mineral fertilizers, intensive training at the community level, which were recommended by the UN Millennium Project Hunger Task Force (UN Millennium Project, 2005b). In addition, planning ahead for the storage of bumper harvests, in order to sell the crop surpluses at peak prices was the crucial fourth point. The results are quick, evident with the first harvest, highly visible, and get communities involved in the project.

5.1.1. Fertilizers

Currently, Africa has the lowest fertilizer use among all regions with an average of 8 kg ha^{-1} of nutrients despite a high prevalence of soils with poor soil fertility (Heisey *et al.*, 2007; Thomson, 2008). Fertilizer application rates for cereals in the Millennium Villages shown in Table 3 averaged 73 kg N ha^{-1} and 18 kg P ha^{-1}, respectively, resulted in profitable value-to-cost ratios, even when the market price of unsubsidized fertilizers and seeds was used and in spite of the sharp increase in prices experienced in 2008. The fundamental reason for that is that the nitrogen use efficiencies in Africa are in the order of 12–16 kg of maize per kilogram of nitrogen fertilizer applied (MDG Africa Steering Group, 2008).

Some of the sources and rates of fertilizers used need to be revised after a better understanding of soil constraints at the different sites. For example, urea is currently used for top-dressing in Koraro, Ethiopia; but the topsoil pH is around 8.2 in some areas. In such circumstances, the urea would volatize and most of the nitrogen applied would be lost. Considering also the visual sulfur deficiency symptoms in maize (Ray Weil, personal communication) we have recommended that the Ethiopian Ministry of Agriculture shift its fertilizer imports from urea to ammonium sulfate for those extensive high pH areas. In Malawi, the standard recommendation is to apply NPS basal fertilizer but crop production is probably not limited by phosphorus in most of Malawi (Benson, 1999; Snapp, 1998). Others have found some soils to be less responsive to fertilizers than others (Vanlauwe *et al.*, 2010) either because the sites are already fairly productive without fertilizer applications (as was the case here for Bonsaaso) or because some low productivity sites do not respond to fertilizer application, because of other overriding limiting factors such as compacted topsoils. The production of a digital map of soil properties currently undergoing in Africa at 90-m resolution will improve the effectiveness of fertilizer applications (Sanchez *et al.*, 2009).

5.1.2. Improved germplasm

Increasing fertilizer application rates alone is not sufficient for increasing yields and will not work unless high-yielding cultivars are used. Many improved high-yielding crop cultivars are available in Africa (Gabre-Madhin and Haggblade, 2004). However, adoption rates are much lower than other continents (Evenson and Gollin, 2001). Local seed companies are emerging in countries like Kenya where investments in the private sector have been encouraged (Ejeta, 2010). The Africa Seed Investment Fund initiated by the Alliance for the Green Revolution in Africa (AGRA) and African Agriculture Capital will invest in small to medium size seed companies in East and Southern Africa (*www.agra-alliance.org*). Once those seeds are available, there is need for distribution at local levels, again AGRA has a program directed toward strengthening the capacity of local agrodealers to deliver quality seed and fertilizer as well as technical information to farmers.

5.1.3. Extension services

In order to be successful, access to fertilizers and seeds must be accompanied by proper agronomic practices. The role of extension services is therefore important in training farmers on improved agronomic practices such as early planting, correct sources, rates, placement, and timely application of fertilizers, appropriate plant spacing, weeding, integrated soil fertility management, harvest, and postharvest management. In the Millennium Villages, farmers were trained in groups of 100 or fewer by government agricultural extension officers, project agricultural facilitators, and master farmers. Such penetration is important for the wide-scale adoption of specific practices and thus increases in yields. Older farmers often commented that they used to know many of those practices, but forgot them due to the absence on such training for years. In much of Africa, government extension services have received little support, and their presence on the ground is either weak or nonexistent due to insufficient staff or lack of operational funds. The MVP empowered local extension agents with transport and new information, and many of them said they were proud to have the resources to practice their profession. The success in Malawi in the 1980s is attributed to the availability of subsidized inputs to farmers coupled with well-supported extension service active at community level (Sofranko and Fliegel, 1989); the same is true nowadays as Malawi became the first African Green Revolution country (Denning *et al*., 2009).

5.1.4. Planning ahead and selling at peak prices

The Sasakawa Global 2000 experience in Ethiopia during the mid 1990s, where successes in using fertilizers, improved seed and extension produced similar yield increases to ours (Quiñones *et al*., 1997), but collapsed when no markets were found to sell the surpluses at an adequate price. Learning from this lesson, the Millennium Villages planned ahead for storage and sale of the expected crop surpluses when crop prices reached their peak value. Market prices are very low at harvest, when small-scale merchants offer to buy grain at minimum prices when farmers need money the most. The grain banks that were established, some using warehouse receipts, provided cash advances to the farmers and sold the surplus at peak prices usually 4–7 months after harvest. The data in Table 6 represent an average of 66% increase in prices when the surplus was sold at peak prices. Not only did farmers double or triple their grain yields but also sold their surplus at much higher prices.

This picture, however, was not uniformly rosy. Yield increases in the drier sites of West Africa were small; millet in Tiby and Potou, and to a lesser extent groundnuts in Potou, a crop not adapted to the limited rainfall, all show unprofitable value-to-cost ratios. There have been no significant breakthroughs on millet yields in West Africa for decades and our experience sadly confirms this.

5.2. Organic inputs and soil management practices

Readers must be wondering why we started with a mineral fertilizer strategy, while many of us have advocated the combined use of mineral and organic sources of nutrients (Nziguheba *et al*., 2002b; Palm *et al*., 1997; Sanchez, 2002; Sanchez *et al*., 1997; UN Millennium Project, 2005b). The primary main reason was the need to quickly reverse decades of soil nutrient depletion and have a quick impact. Second, the quality and amounts of organic inputs in many of the Millennium villages situations are insufficient as the sole sources of nutrients. Suggestions to begin with improved legume tree fallows were met with advice of the Sauri Agricultural Committee in early 2005 that improved fallows would take a year to develop, thus delaying a significant increase in yields for at least a year.

Getting organics into these degraded farmlands is a challenge. Of the various types of organic resources produced under subsistence farming, crops residues, manure, and compost, none are produced in sufficient quantity and adequate quality to provide nutrients required for crop production (Palm *et al*., 1997; Palm *et al*., 2001). In addition, crop residues have often multiple uses (livestock feed, fuel for cooking, and fencing materials) that limit their use as soil amendments. With the doubling of crop yields, however, crop residue production also doubles, enabling farmers to use crop residues for soil management either directly or through compost and manure. The amounts and quality of animal manure is usually limiting, so it is likely to be a supplement, and a good one, particularly when point-placed.

No sustainable farming relies solely on mineral fertilizers. Now that yields have increased and remain high, the current thrust is to bring the organics in with a priority to use nitrogen fixing trees or herbaceous legumes *in situ*, interplanting them into the maize crop and allowing it to grow during the dry season. This is to avoid the large transport cost of organic sources produced outside the field, which limits their use a supplement. Improved leguminous fallows are a well-documented practice, and can fix 50–100 kg N ha^{-1} per year, recycle nutrients leached to the subsoil particularly potassium, as well as carbon, control weeds, and in the case of trees provide firewood. But after initial adoption most farmers abandon the practice (Franzel *et al.*, 2002), while a small proportion—the best farmers—thrive on it. We feel the main reason for abandonment is the opportunity cost incurred when land is not used for growing a short rains crop in bimodal systems, or even sacrificing a full rainy season crop in unimodal systems to allow the trees to grow. Financial incentives just like fertilizer subsidies are needed; we intend to develop such incentives for the village clusters that are not in the semiarid or arid tropics. Grain legumes are also being promoted and financed, as sound crop rotation. But beans, soybeans, and groundnuts take most of their fixed nitrogen away in the grain, leaving little for the subsequent maize crop. Grain legumes in Malawi are estimated to add about 30 kg N ha^{-1} to the subsequent crop (MDG Africa Steering Group, 2008), a very desirable amount, but not sufficient to replace mineral nitrogen applications.

Organic inputs are important for building soil organic matter and improving physical and biochemical properties of soil leading to improved fertilizer use efficiency, soil quality, and to sustainable crop production but they can be also a valuable source of nutrients, particularly N, thus reducing the quantity of fertilizers requirement (Alley and Vanlauwe, 2009; Place *et al.*, 2003). N fixing trees for improved fallows or cover crops are particularly important sources of N to complement fertilizers and they also produce large quantity of biomass for soil organic matter building. Yields obtained through improve fallows or cover crops are 60–80% higher than yields without fertilizers but are significantly lower than those obtained with mineral fertilizers (Sileshi *et al.*, 2008). As fertilizer subsidies are reduced or removed and fertilizer prices remain high, farmers have been trained in and supported in different practices to increase the use of these high quality organic inputs. Despite the promising yields and money saved in the reduced amount of N fertilizers that are required, adoption by farmers in the Millenniun Villages have been fairly low both in the number of farmers and the size of land they put under these soil management practices. Small land sizes, labor requirements, and the time and land need to produce improved tree fallows have been cited as factors hindering adoption (Keil *et al.*, 2005; Kiptot *et al.*, 2007). Evaluations of the process of adoption and factors that may influence increased adoption are underway in the MV sites where these practices are being promoted.

We have also not included yet minimum tillage practices, due to insufficient research evidence (Giller *et al.*, 2009). We know this is not possible in structurally insert sandy Alfisols of West Africa like those of Tiby, but there is potential in other village clusters with loamy to clayey Alfisols and Oxisols.

5.3. Improved nutrition

An indicator for measuring progress toward the MDG of halving the percentage of people suffering from hunger is the percentage of the population below the minimum dietary energy intake (Palma *et al.*, 2009). When maize yields surpassed the 3 t ha^{-1} mark (or equivalent in other crops) in 78% of the village households, the minimum annual energy requirements were achieved and usually exceeded.

But meeting household minimum caloric requirements is insufficient in itself to reduce malnutrition (Barrett, 2010). It is the first step in the integrated approach to alleviate hunger and malnutrition in the Millennium Villages. Our nutrition strategy includes an emphasis on food-based models that enhance the security and quality of the diet through local production, processing and storage of foods, the promotion of agricultural biodiversity, complemented by community education and development. Such strategy often falls outside the traditional scope of clinical nutrition intervention like nutritional supplementation (Fanzo *et al.*, 2010). Diets in many rural areas of Africa are limited not only by the amounts consumed but are often based on a staple cereal or root crop with high energy content but low nutritional quality. A major emphasis in the Millennium Villages sites is to support agricultural diversity to include nutritious crops; such as the many African leafy green vegetables, which have been disappearing from farms and diets (National Research Council, 2006), and other nutritious crops such as orange-fleshed sweet potato, fruits, and livestock both at home and in the school feeding school programs (Table 7). Improving nutrition also is a cultural matter and involves changes in food habits particularly if the crops promoted are new to the communities. Educational materials and training sessions with farmers, particularly women, on the importance of nutrition, the nutritious value of various foods, and means of preparing foods are key components of the agricultural diversification and nutrition strategy. Preliminary results from Sauri after just 3 years of the integrated nutrition strategy already show a reduction in chronic malnutrition, measured as underweight (low weight for age) children under 2 years of age from 19% to 6% and stunting (low height for age) from 73% to 35% after 3 years of interventions (Fanzo *et al.*, 2010). One supplement that is absolutely necessary is iodized salt to combat iodine deficiency, which is unfortunately prevalent in areas away from the oceans.

5.4. Diversification, primarily with irrigation

Nobody is likely to escape the one-dollar-per-day absolute poverty trap by growing maize on half or one hectare no matter how high the yield. The way forward is crop and enterprise diversification. Diversification to high-value crops depends first on the markets, determined through a market survey and analysis. Efforts to expand the scale and efficiency of these activities involve capacity development in aspects of market access such as price variations, produce quality, group selling, and record keeping; and linking farmers to microfinance institutions for saving and microcredit access such as Equity Bank in Sauri, Opportunity International mobile banks in Mwandama, and the Mutuelle d'Epargne et de Crédit in Potou. Each of these institutions provides basic services like credit and saving accounts to villagers.

Most of the high-value crops being promoted in the villages require some form of irrigation. In most sites, farmers were using water from wells or streams and irrigating with buckets. The project has promoted expansion of water sources through rainwater harvesting in small farm ponds, small-scale dams and water diversion in small channels. Pumps and drip irrigation systems have been introduced. The location of Potou in the coastal zone, and of Tiby on the Niger River has enabled the production of high-value irrigated vegetable crops that play a major role in providing a safety net in the event of food shortages due to crop reductions and failures.

In addition to water for irrigation of cash crops, there is a need to find ways to provide water to get staple crops through critical dry spells and avoid crop failures. Water harvesting at the landscape level, which recharges ground water and shallow wells, is also used to fill mini dams and storage ponds in Koraro. This practice should be extended to other village clusters that are likely to experience severe dry spells.

5.5. Subsidies and the transition to credit

Subsidies programs have been used in Africa with mixed results. A primary concern has been the disproportionate benefits received by the larger and relatively better-off farmers, even when the target was for poor farmers (Akinola, 1987; Minde *et al.*, 2008). Implementation procedures and the ability to manage subsidies are critical for the success and impact of subsidy programs (Minde *et al.*, 2008). Recently, the concept of smart subsidies has emerged to try and overcome some of the problems. Minde and Ndlovu, (2007) describe "smart" subsidies as those that target farmers who would not normally use purchased inputs, or target areas where fertilizer would have larger impacts on yields; in addition those programs should be results oriented and have a time frame of implementation.

The Millennium Villages subsidy program followed most of the conditions set forth above as follows: (i) targeted poor communities who were using little or no fertilizers and improved seed; (ii) took place in areas with depleted soils where response to inputs is generally high; (iii) included mostly small farm areas, generally up to 1 acre (0.4 ha), which would not attract large-scale farmers; (iv) involved village agriculture committees in the distribution of inputs to limit the leakage to those not targeted; (v) increased production of major crops, with the first goal of reducing hunger; and (vi) progressively reduced the subsidy during the 5 years of the project. The subsidy program was not without leakage and selling to farmers outside the intervention area, some elite capture or preference to male farmers, but overall increase in yields throughout the clusters indicated that most farmers were receiving the inputs and using them on their staple crops.

Eventually, the aim is to have national subsidy programs operating in Africa to provide small holder farmers with access to inputs; most notably is the national input support program of Malawi (Denning *et al.*, 2009) but currently only a few countries included in this review have input subsidy programs. As a consequence, alternative solutions were developed to provide continued access to inputs; these alternatives ranges from loans through financial institutions to revolving funds set up through community-run cereal banks.

Farmers paid back loans or subsidies in cash, in-kind with grain, or a combination, again varying from site to site. The major challenges for the transition from input subsidies were: (i) the lack of financial institutions willing to administer credit to poor farmers; (ii) the lack of sufficient capacity or financial capital of local microfinance institutions to provide or manage loans and collect repayment; and (iii) the existence of vulnerable groups that cannot or will not take out loans.

5.6. Safety nets

For the vulnerable groups mentioned above, comprising perhaps 10–20% of the households, there is need to identify them, the characteristics that make them vulnerable, and provide means of supporting them. For those that are still capable of farming, direct subsidies could be targeted for agricultural practices appropriate for these groups. For example, in Sauri, widows farming extremely small plots of land have requested support for starting poultry production. Cash transfers or permanent subsidies are likely to be needed for the poorest and most vulnerable in the communities. Food for Work is an example of such support programs. The Koraro village cluster in Ethiopia participates in the MERET program of the World Food Program

(WFP) and the Ethiopian government, in which food-insecure communities are provided with food for payment on work in environmental rehabilitation projects. The environmental rehabilitation often also results in improved water capture and management. The MV project is exploring such collaborative efforts in other sites.

5.7. Adaptation to climate change

Unlike the Green Revolution in Asia which centered on irrigated crops, the African Green Revolution must deal with the challenges of rainfed agriculture to be successful (Binswanger-MKhize and McCalla, 2010; Thomson, 2008). Six out of the eight sites presented in this chapter produce their staple crops exclusively from rainfed agriculture. Even in the two sites where irrigation is practiced, Tiby in Mali and Potou in Senegal, the major subsistence crops (millet, groundnuts) are rainfed. This represents the situation in most of Africa where 96% of agriculture is rainfed (Hazell and Wood, 2008). Yield reductions due to low or erratic rainfall is one of the main reasons for low crop production in sites located in semiarid to arid zones, Tiby, Koraro, and Potou. In addition to inter and intra annual variability in rainfall that determines crop yields, climate change is predicted to impact livelihoods the most in the tropics and subtropics, particularly in Africa, where many poor, smallholder farmers depend on agriculture and have few alternatives for adaptation (IPCC, 2007; Thornton *et al.*, 2009). Developing climate risk management strategies is crucial to the longer term success of the Millennium Villages and the African Green Revolution, where the investments and savings accrued through improved crop production and diversification can be wiped out with two successive crop failures. Strategies being piloted in some village clusters include use of seasonal climate forecasting probabilities to better inform selection of crop varieties and crop management and rainfall/crop insurance programs (Hellmuth *et al.*, 2009), and Food for Work programs.

Crop or drought insurance programs are being tested in Africa for climate risk management. The MVP partnered with the International Research Institute for Climate and Society (IRI) and the reinsurance company Swiss Re to develop an index insurance scheme based on NDVI satellite data and local rainfall data (Hellmuth *et al.*, 2009). The index insurance was developed primarily to explore ways to insure the development goals of the project but could perhaps be more widely adapted to individual insurance programs using lessons from projects in Ethiopia (World Food Program, 2007) and Malawi (Hess and Syroka, 2005; Osgood *et al.*, 2008). This is work in progress.

A strategy for coping with climate variability and change is to utilize the existing rainfall more efficiently as has been illustrated by Rockström (2003). He showed that at cereal yields of 1 t ha^{-1} almost two-thirds of the water vapor flow is soil evaporation and one-third transpiration; but for yields of 3 t ha^{-1} and above, when the crop canopy closes, two-thirds of the vapor flow is through transpiration and one-third through evaporation. Basically, this suggests that increasing yields in SSA from 1 to 3 t ha^{-1} can be done without increase in water, just better management to assure more of the water moves through transpiration rather than evaporation.

Researchers at the International Crops Research Institute for Semiarid Tropics (ICRISAT) confirmed this assumption by modeling 50 years of seasonal rainfall records in a semiarid area, Bulawayo, Zimbabwe (Cooper *et al.*, 2009). With low nitrogen applications, maize yields varied from 0 (a crop failure during the well-known El Niño drought of 1992) to a maximum of 1.6 t ha^{-1}, with an overall mean of 0.86 t ha^{-1}. When recommended nitrogen applications (52 kg N ha^{-1}) are used, average yields increased to 2.75 t ha^{-1}, with a range from 0 to 3.8 t ha^{-1}, including three widely spaced crop failures in 50 years. Overcoming nitrogen deficiency made a quantum leap in overall yields in spite of seasonal rainfall variability, tripling them from the SSA average of less than 1 t ha^{-1} to almost 3 t ha^{-1}, the target of the African Green Revolution.

6. Conclusions

The results presented here demonstrate that the initial interventions of the African Green Revolution, access to subsidized fertilizer, improved crop germplasm adapted to local conditions, and field-based extension services, are able to quickly and dramatically increase maize yields to 3 t ha^{-1} and above to a large number of farmers. Doubling of teff yields were also realized in Ethiopia. These successes were not realized with millet and groundnut yields in the semiarid zones of West Africa.

An increase in staple crop production is only a first step in reducing hunger; but to address wider food and nutritional security and poverty reduction, other steps are necessary. The increased harvests achieved in the MVP sites were potentially sufficient to meet basic caloric requirements of the Millennium Villages community but in order to address undernutrition or hidden hunger of protein and micronutrient deficiencies, these harvests of staple crops must be accompanied by an integrated nutrition strategy that includes nutritional diversity, either through agricultural diversification or the ability to purchase foods through higher incomes, and safety nets for vulnerable groups.

The investments in seeds and fertilizers were profitable for farmers if surplus harvests were stored and sold later in the off-season at peak prices. With small farm sizes the surpluses would be generally small and insufficient to reduce poverty significantly. A transition from staple crops to cash crops is essential to realize substantial profits but requires appropriate market studies to identify the better options for farmers. Farmers must also be trained in the new crop technologies with an additional focus on product quality and they must often be organized into producers groups that can negotiate higher prices and linkages to buyers. Investments in small-scale water management and irrigation become important for production of high-value crops but financial institutions that provide loans and savings for agricultural investments are an essential element that is currently lacking throughout most of rural SSA as is a reliable network of certified agro input dealers.

In the end, improving agriculture in itself is unlikely to get rural communities in SSA out of poverty. The ability to produce sufficient food is diminished if people are suffering from malaria, HIV/AIDS, or neglected tropical diseases. The ability to enter market-based economies is hampered by lack of education. The synergies between reducing hunger and controlling diseases, between school meals provided from surplus harvests and increased learning, are all too evident. The challenge remains to overcome our sector barriers and to think and act in a multisectorial way if the overall goals of the African Green Revolution and the MDGs are to be attained.

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