CN161

Maize-Bean Conservation Agriculture Systems

A proposal for

Increasing Crop Water Productivity in the Victoria Nile Basin Using Stress Tolerant Maize and Bean Varieties in Conservation Agriculture Systems

Submitted to the

Water & Food Challenge Program

By

CIMMYT (International Maize & Wheat Improvement Center)

In collaboration with:

CIAT (Centro Internacional de Agricultura Tropical)
TSBFI (Tropical Soil Biology Fertility Institute of CIAT)
IFDC (An International Center for Soil Fertility and Agricultural Development)
NARO (Kawanda Agricultural Research Institute), Uganda
KARI (Kenya Agricultural Research Institute), Kenya
LZARDI (Lake Zone Agricultural Research & Development Institute), Tanzania
and **CARE-Kenya**

September 2003

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Project title

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Brief title

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Executive Summary

Population in the Victoria Nile catchment is one of the densest and fastest growing in Africa. Food security is a major concern. The region depends heavily on the maize-bean system, with these staples ranking first and second in importance. Population pressure has led to exploitative agriculture and declining soil quality including fertility, organic matter, physical properties, and rainwater infiltration. Reduced crop biomass, ground cover and root development contribute to greater soil erosion. Poor water conservation exacerbates variability in rainfall. Poor productivity reduces capital for investment in solutions, aggravating the decline. The net result is increased run-off and erosion, reduced water productivity, and soil and water quality, and land productivity; and stagnant or declining per capita food production over the last 30 years.

Soil and water quality will not be improved without viable agricultural productivity. While the problem is complex, synergies can be gained by combining crop and natural resource management components, as well as institutional and socio-economic analysis. In the past these components have often been employed individually. Our purpose is to improve food security and downstream water quality through the integrated use of improved cultivars, conservation agriculture (CA) techniques, and soil fertility improvement.

Our objectives, and means of achieving them are:

- To select, evaluate and disseminate moisture stress tolerant and nutrient use efficient maize and bean varieties adapted to local biotic stresses that increase water productivity and reduce input requirements. Abiotic stress tolerant crop varieties are already under development, and will be tested in systems with CA practices.
- To evaluate and adapt CA technologies for maize-bean systems that improve crop water productivity and increase crop production and yield stability. Soil and nutrient management components will include fertilizers and legumes, cover crops, reduced tillage and subsoiling as appropriate.
- To evaluate the potential impact of CA adoption in maize-bean systems on water and soil dynamics and quality at the watershed level. Modeling and GIS will be employed for this purpose.
- To develop policy recommendations for increased adoption of CA technologies, improved seed, fertilizers and pest control products in maize-bean systems. Farmer constraints will be identified, and input/output markets and the institutional framework analyzed.

Impacts from the adoption of technology will include: increased food security through improved productivity and yield stability of maize-bean systems; increased returns on investments, encouraging greater use of fertilizers; improved soil health (increased organic matter, biological activity, soil structure and fertility).

Medium to long-term benefits of reduced run-off, soil erosion and evaporative losses and enhanced water infiltration will reflect in increased stream flows and reduced siltation, improved downstream water quality, and will be moderated by the extent of concerted community adoption at the watershed and catchment level.

Diffusion of technologies will be achieved through existing crop and soil research networks of NARES and NGOs with experience in technology transfer. Adoption of CA technologies will have immediate benefits for female-headed households by reducing labour requirements for land preparation and weeding particularly where HIV/AIDS has reduced labour availability and increased women's workshare in farming activities.

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Budget Requested From CP (in US$)

US$ 1,998,000

Budget Offered as Matching Funds (In US$)

US$ 1,465,000

Total Budget (In US$)

US$ 3,463,000

Duration of Project

FIVE years

Coverage of Basins

Upper Nile Basin in the catchment of Lake Victoria; three field sites (Western Kenya, Northwestern Tanzania and Eastern Uganda).

Coverage of Themes

Crop Water Productivity Improvement (Theme 1)	**60 %**
Multiple Use of Upper Catchments (Theme 2)	**20 %**
Aquatic Ecosystems and Fisheries (Theme 3)	**0 %**
Integrated Basin Water Management Systems (Theme 4)	**10 %**
Global and National Food and Water System (Theme 5)	**10 %**

Background and Justification

Social: The upper Nile region surrounding Lake Victoria is one of the most densely populated of Africa with up to 1200 persons km^{-2} in parts of Kenya.[1] Population growth rates are among the highest in the world. In 1985, 32% of the Kenyan portion of the catchment was occupied by agriculture and, with population having doubled in the interim, deforestation and excessive cultivation with little input use have been the predominant land use trends. Additionally, the area has one of the poorest rural populations in the world. The pervasive poverty has hindered sustainable use of land resources increasing degradation which is now the single most important threat to agricultural productivity.[2]

Much of the population depends on rainfed agriculture for its sustenance upon the cultivation of maize (*Zea mays*) and common beans (*Phaseolus vulgaris*) which rank first and second in importance as food staples in this region.[3] Food security is a major concern. Maize-bean intercropping is practiced on >80% of the area in the Kenyan catchment, 45-80% on the northern shores in Uganda, 25-45% on the west (Uganda and Tanzania) and >80% in the southern catchment (Tanzania).[4]

Biophysical: Soil productivity in the lake region has been in decline for decades as increased population pressure and the high cost of inputs have led to excessive cultivation, declining soil fertility and soil physical degradation[5] characterized by low soil organic matter (SOM), poor structure, hardpans and poor infiltration of rainwater. Improper agronomic practices have led to enhanced soil erosion,[6] estimated in the order of 5-10 t/ha/yr.[2] A soil degradation study in Winam Gulf, Lake Victoria, showed that even moderately accelerated soil erosion had highly negative impacts on soil physical, chemical and biological properties.[2] Sheet erosion, for example, decreased SOM stocks by 17-25% and exchangeable bases by 39-47% over intact controls.[2] Over the last 40-50 years, phosphorus (P) levels in the lake have increased 2-3 times.[7] According to modeled estimates,[8] about 50% of the nitrogen (N) and 56% of the P input is due to run-off from surrounding agricultural land. Several rivers draining into Lake Victoria have very high levels of turbidity resulting from over-cultivation of hillslopes.[9] Associated nutrients (especially P) transported with sediment adversely affect the water quality in the lake, favouring dominance of N-fixing bacteria and the spread of water weeds such as hyacinth[2] which has had direct economic impacts on commercial marine transportation and fish landings.[10]

Soil fertility depletion on smallholder farms has been the fundamental biophysical cause for soil and water degradation as well as stagnant or declining per capita food production in the Victoria Nile catchment during the last 30 years. Reduced crop biomass, ground cover and root development due to nutrient depletion contribute to greater soil erosion. Poor soil and water conservation exacerbates the high variability in rainfall, leading to large fluctuations in outputs and prices. Less agricultural productivity reduces capital for investment in solutions, creating a vicious cycle that aggravates and accelerates the decline. The net result is increased run-off, reduced crop water productivity (CWP), increased erosion, reduced water quality and land productivity, and food insecurity.

Solutions: Measures that address rural poverty are also appropriate in redressing the trends in soil and water degradation in the Victoria Nile catchment. Increases in productivity of agricultural land that already has a high potential, particularly by removing P and N nutrient constraints, will ultimately reduce pressure on fragile lands within the lake catchment.[2] Components of improved CWP and water quality include:

- Drought tolerant maize and bean varieties that make more efficient use of limited water to better withstand intra-seasonal periods of moisture stress.
- Improved genetic adaptation of maize and beans to sub-optimal fertility levels.
- Improved plant nutrition, especially N and P, through soil fertility management (inorganic fertilizers, organic manures, legumes) to improve plant development and root growth to make better use of available soil water.
- Subsoiling to break hardpans and improve root penetration and water infiltration.
- Soil moisture conservation and rainwater harvesting methods to reduce rainfall run-off and erosion, increase water infiltration, and reduce evaporative losses from the soil.

CIMMYT has made significant gains in developing N-use efficient and drought tolerant maize varieties. Hybrids adapted to the lake zone and mid-altitude ecologies of Eastern and Central Africa (ECA) are now available that yield 50% more under low N fertility and more than double the yield of the best local hybrid under mid-season drought conditions.[11] CIAT has also progressed in breeding beans for tolerance to both drought and low P.[12] CIMMYT and ECAMAW (ECA Maize and Wheat Network) scientists have gained considerable experience with leguminous cover crop and green manure species in maize systems[13] as well as water harvesting methods using tied ridges. CIMMYT has had substantial global success in developing and disseminating conservation agriculture technologies, especially in wheat-based systems.[14]

According to Rockstrom et al.,[15] the keys to improved water productivity and mitigating intra-season dry spells in rainfed agriculture are maximizing the amount of plant available water and the plant water uptake capacity. This implies systems that partition more incident rainfall to soil storage and less to run-off, deep percolation and evaporative loss, as well as crops that provide more soil cover and root more deeply. Animal drawn rippers and sub-soilers could increase water productivity among small-scale farmers by increasing water infiltration and storage as well as root penetration.[15] Improved soil fertility would also improve CWP by increasing root growth and development.

Adoption of nutrient and water efficient technologies is primarily constrained by lack of knowledge[9] exacerbated by weakened extension services and their disconnect with researchers, as well as low use of farmer participatory research methods that increase the potential for adoption of new technologies by involving farmers in their development. However, adoption of the technological components of CA ultimately depends on the policy environment that determines the economic viability of measures such as fertilizer use that can enhance the impact of all components on CWP and food security. The potential contribution and economic viability of inorganic fertilizers must be reexamined in the light of national policies affecting fertilizer prices and international aid policy. Nutrient and water use efficient genotypes invite reassessment of past estimates of return on investment from fertilizers.

Integration For Synergies: Maize-bean system components interact strongly but past initiatives have often dealt with individual components and have not addressed their impact on water as a resource. Synergies are to be gained by combining genetic, crop management and soil-water management components, as well as institutional and socio-economic analysis. By developing and exploiting these synergies, this project will enhance crop water productivity, improve soil and water quality, and reduce the negative downstream impacts of agriculture on water quality in the Nile River basin.

Goal

Improved food security, well-being and water quality for resource poor smallholder farmers in the Victoria Nile catchment through more water productive agriculture based on drought tolerant and nutrient use efficient maize and bean cultivars, conservation agriculture techniques, and enhanced soil fertility.

Specific Objectives

This project directly targets smallholder farmers in the densely populated Upper Nile catchment around Lake Victoria, and indirectly targets downstream users of the Lake Victoria/Upper Nile waters by mitigating the impact of resource-poor smallholder farmers on water quality. Specific objectives listed below are focussed at the plant level (Objective 1), the crop/field level (Objective 2), the agro-ecosystem level (Objective 3) and the policy level (Objective 4), with emphasis on soil/water/crop management and policy, which were ranked first and second at a recent priority setting meeting for the Nile River Benchmark Basin in Kampala, Uganda.[*] The specific objectives are:

1. To select, evaluate and disseminate moisture stress tolerant and nutrient use efficient maize and bean varieties adapted to local biotic stresses that increase CWP and reduce input requirements.

   This objective will provide resource-poor smallholders with greater maize and bean yields under moisture and nutrient-stressed conditions, greater yield stability and hence food security, and reduced fertilizer requirements through higher use efficiency.

2. To evaluate and adapt CA technologies for maize-bean systems that improve water conservation and increase crop production and yield stability.

   This objective will greatly improve yields through the benefits of reduced tillage and leguminous cover crops on increased water availability and soil-N fertility while reducing erosion and nutrient and sediment loads in rivers discharging into the Victoria Nile.

3. To adapt GIS and modeling tools for quantifying CWP of maize-bean systems at the field level, and apply them to project the potential impact of improved CWP at the watershed and basin level.

[*] Challenge Program – Water & Food. 2nd Nile Basin Kick-off Meeting, 5-6th August 2003, Kampala, Uganda.

This objective will result in improved models that accurately simulate evapotranspiration and the complex interactions of genotype, soil, weather, and management on crop growth and development. Geo-referenced information on soil types, land use, topography, and climate incorporated into a GIS linked to the models will enable projections of impact and scenario analysis for scaling up and out.

4. To assess the socio-economic impact of, and develop policy recommendations for increased adoption of CA technologies, improved stress tolerant varieties, and inputs in maize-bean systems.

This objective will develop recommendations for policy makers and institutions to improve the enabling socioeconomic environment for CA technologies and varieties enhancing conditions for adoption. Micro- and macro-scale benefit:costs analyses of CA will provide information to enable its adaptation to different environments, and make recommendations for scaling up and out in the basin.

Activities and Methodology

This project will build on the complementary strengths of the participating institutions to exploit potential synergies of maize-bean production system components in the context of CA technologies. This on-going component research is being implemented largely through highly collaborative research networks (ECAMAW, ECABREN, AfNet) operating under the ASARECA umbrella in ECA. This project provides an opportunity for increasing collaboration between the Networks, which will be critical both for maximizing potential impacts and for enhancing diffusion of CA technologies.

Project outputs and activities span the scale from field plot to smallholder farm and farming community to watershed. The major focus is at the plot and community level but includes the development of tools to estimate the potential for scaling up and out and the consequent impact of doing so on water quality at increasing scales of adoption.

The project will be implemented at three benchmark sites, one in each of the three countries bordering Lake Victoria (Kenya, Tanzania and Uganda). Sites were chosen on the basis of dominant cropping systems (maize-beans), soil type, rainfall, and elevation in consultation with project partners at a meeting held in Kisumu, Kenya, on August 8, 2003 (Annex 1). Activities for each objective are described below. Responsibility for implementation and the timeframe for each activity are shown in the Gantt Chart (Annex 2) and the section on "Roles of Project Researchers…".

OBJECTIVE 1: "… moisture stress tolerant and nutrient use efficient maize and bean varieties …"

CIMMYT and ECAMAW Network scientists have developed maize varieties with tolerance to mid-season moisture stress (at the critical flowering stage), low soil-N fertility and *Striga* as well as resistance to major biotic stresses. Moreover, adapted imidazolinone herbicide-resistant (IR) cultivars are ready for commercial release. IR-maize seed coated with low doses of herbicide provides 100% control against *Striga*.[16] CIAT scientists have developed P-use efficient bean genotypes that also possess adaptation to moisture stress.[12] However, these genotypes require further selection for adaptation to local biotic stresses. Identification and understanding of plant traits important for efficient nutrient and water use will assist in devising improved crop, water and nutrient management in CA systems. The interaction of soil fertility and management is important in increasing CWP. Moreover, management of fertilizer inputs will require adjustment for nutrient use efficient crops in CA systems.

Activities:

1.1 Evaluate drought tolerant, N-use efficient maize varieties with resistance to local biotic stresses in on-farm trials with farmer participation.

The "Mother-Baby trial" methodology[17] will be used to evaluate elite maize cultivars in the target areas. With this method, varieties are compared under researcher managed conditions in "Mother" trials with both optimal and suboptimal levels of inputs, and in subsets of the trial ("Baby" trials) on-farm under farmer management.

1.2 Select and evaluate drought tolerant, P-use efficient bean varieties with resistance to Angular Leaf Spot (ALS), root rots and/or Bean Stem Maggot (BSM).

Root rots and BSM affect the ability of plants to absorb nutrients and thus interact strongly with soil fertility. Available P-efficient, drought-adapted genotypes with vigorous roots and abundant biomass will be tested for their response to these environments and their multiple biotic factors. Additional populations will be created to augment tolerance to abiotic stress and to introduce biotic stress resistance.

1.3 Determine genotype × environment interactions of drought tolerant and nutrient use efficient genotypes under different water and nutritional regimes, and the roles of different plant traits in sub-optimal environments.

Genotypes with known traits (enhanced grain filling, different root architectures, etc) will be planted in different environments to determine the value of these traits across sites. Given the importance of maize-bean intercropping in the region, elite adapted selections will be evaluated under both monocropping and intercropping conditions using Mother-Baby trials.

1.4 Demonstrate and disseminate maize and bean varieties adapted to local agro-ecological conditions and stresses.

CIMMYT experience has shown that "Mother-Baby" trials are highly effective in assessing farmer preferences as well as stimulating interest in and demand for improved cultivars that farmers have identified in their plots. Furthermore, information gained from them can be used to support the variety release process.

OBJECTIVE 2: "… CA technologies for maize-bean systems …"

The project will evaluate CA component technologies (such as residue retention, cover crops, minimum tillage, subsoiling, tied ridges, organic and inorganic fertilizers) successfully demonstrated elsewhere[14] and adapt them to the maize-bean systems commonly practiced by smallholders in the Victoria Nile catchment. The approach will be to initially evaluate systems under researcher-managed (controlled) conditions at benchmark sites then to move rapidly to on-farm farmer-managed demonstrations and experimentation with the most promising alternatives. Farmer participation will be fostered through collaboration with NGOs active in the target communities.

Activities:

2.1 Evaluate and adapt CA technologies to local maize-bean systems.

Initially, a workshop will be convened to describe current farmer practices, maize-beans cropping systems, and recommendation domains (land types, agroclimatic conditions, socio-economic circumstances) in each target area. Alternative CA technologies will be identified for adaptation to current cropping systems and evaluated under researcher-managed conditions at benchmark sites. Using the benchmark trials, field days will be organized to allow farmers to observe and discuss the technologies.

2.2 Identify and/or organize farmer groups for mobilization and training in group dynamics and community organization to facilitate adoption of CA technologies.

Within the framework of their community development activities, NGOs will identify and organize farmer groups to facilitate adoption of CA and stress-adapted maize and bean varieties. Researchers, extension agents and NGO partners will receive training on CA technologies making use of benchmark trials and demonstration trials established in the community.

2.3 Facilitate adaptation and adoption of CA technologies through pilot demonstrations and farmer experimentation in target areas.

Using demonstration trials as an entry point, NGO extensionists assisted by researchers will foster farmer experimentation with CA technologies in maize-beans systems. Frequent informal and formal interactions with farmers, including participatory evaluations, economic analysis and socio-economic surveys, will help to identify technological problems and adoption constraints, providing feedback to researchers to overcome them.

2.4 Determine the effects of CA technologies on water infiltration, storage and run-off, and soil erosion and quality.

Using benchmark and demonstration trials, soil scientists will periodically monitor the effects of CA systems on run-off, infiltration rate and soil water storage as well as associated soil properties including SOM content, penetrability and structure for the duration of the project. Results will feed into activities of Objective 3.

2.5 Determine the effects of CA techniques on crop development and productivity, and monitor their effects on crop pests and pathogens.

Maize and bean crop development and productivity will be monitored under conventional and CA systems to determine the effects of improved water infiltration and storage on yields as well as intra-seasonal moisture stress. Since pest populations may change under different management systems, crop pests (weeds, termites, borers, etc.), pathogens and diseases will be periodically monitored in benchmark and demonstration trials.

OBJECTIVE 3: "…GIS and modeling tools for quantifying CWP of maize-bean systems…"

Processes and interactions that determine crop yield and water productivity will be described using process-based simulation models. Comprehensive models (e.g., DSSAT[†] family) that simulate plant growth and development, evapotranspiration, soil water balance, nutrient dynamics, and residue decomposition at the field level will be tested and improved upon. Model evaluation and data collection from field experiments will be closely linked. Validated and calibrated models together with GIS data will facilitate identification of target areas where potential for significant adoption and impact is greatest. Furthermore, model analysis will assist in estimating the scale of adoption necessary to have impact at higher levels of aggregation and will provide tools to assist policymakers and development agencies to target resources for scaling up and out of CA technologies and improved cultivars.

Activities:

3.1 Develop data for parameterization and calibration of crop growth models for local soil types, climatic conditions and CA practices.

Both historical and new experiments (e.g., activities 2.4 and 2.5 above) in the region will be used to construct databases containing at a minimum data on crop performance (growth analysis, yield components), soil profile characteristics, daily weather, and soil water, nutrient and carbon dynamics as affected by crop and soil management.

[†] Decision Support System for Agrotechnology Transfer (http://www.icasa.net/)

3.2 Develop and test subroutines to improve model sensitivity to maize-bean intercrop systems and soil management practices identified with CA technologies (e.g., surface residue retention, minimum tillage).

Model evaluation will begin with the DSSAT CERES-Maize and CROPGRO-Bean models which will be calibrated for local cultivars and conditions. Current released versions do not simulate intercrops or tillage processes. However, subroutines that describe the impact of tillage as well as a residue layer on rainwater retention, infiltration, soil temperature and moisture regime have been developed by CIMMYT researchers and are ready to be tested in and adapted for maize-bean cultivation systems.

3.3 Acquire spatial data of watershed soils, topography and hydrology to scale up plot and field-scale model simulations and organize these together with plot and community data into a GIS.

Available spatial data for the watershed, and project-generated information, will be compiled into a unified GIS database. This information base, including inputs from Activity 3.4 and Objective 4 and generated outputs from DHI tools amongst others, will be used to delineate recommendation domains within which the impact and adoption of specific CA technologies or improved cultivars is likely to be maximized. All information will be made widely available through user-friendly decision-support tools.

3.4 Combine spatial data and plot-level simulations in a GIS to develop predictions of the impact of CA, stress-adapted varieties and soil fertility improvement on water use and dynamics in the watershed.

Direct linkages between crop growth models and GIS, using established software created by IFDC, will be used to extrapolate model results beyond the plot level to produce impact predictions on a wider scale. Some of the information layers generated in activity 3.3 will provide inputs for this activity and resulting model outputs will be components of the distributed decision-support tools.

OBJECTIVE 4: "… socio-economic impact and policy recommendations for increased adoption …"

Successful adoption of improved technologies by farmers depends not only on technical efficiency, but also on economic feasibility and a favorable market environment. Stress-tolerant varieties and CA technologies promise greater productivity and yield stability with lower inputs. Nevertheless, degraded soils in the Victoria Nile catchment require replenishment of nutrients such as P that are not provided through organic sources. Unfortunately, fertilizer prices increase 100-200% between the Kenyan coast and the Lake Victoria catchment. Economic analysis of the technologies combined with an analysis of the input markets and factors affecting farmer access to and use of credit and extension services is necessary to provide recommendations for scaling up as well as policy recommendations to ease prices and increase input usage and adoption of CA technologies.

Activities:

4.1 Conduct socio-economic and gender analyses to estimate demand for CA technologies and determine constraints to adoption.

Participatory Rural Appraisals (PRAs) will assess demand for CA technologies in the pilot areas. Participatory techniques will reveal selection criteria for new technologies, preferences for established technologies, and constraints. Wealth ranking, village mapping, and resource flow mapping will provide information on farming systems and insights on constraints to adoption of CA technologies. Household surveys will provide baseline data to monitor adoption and determine factors that influence adoption.

4.2 Analyze input/output markets to determine their effects on adoption of CA technologies.

Input and output price trends will be obtained from secondary data, and factors that influence them will be analyzed. The dynamics of input and output markets will be further analyzed through interviews of key players (seed producers and retailers, fertilizer importers and stockists, maize traders and transporters).

4.3 Analyze the institutional framework in which farmers operate, determine its constraints and identify means to overcome constraints to enhance adoption of CA, improved varieties and inputs.

The structure and working of agricultural institutions will be analyzed through PRAs, visits to major credit providers and discussions with government (extension, market information, rural credit) and non-government (NGOs, projects, donors) services. PRAs will reveal institutes active in pilot areas and household surveys will provide data on access to services.

4.4 Assess the potential impact of CA technologies on farmers' income and rural poverty.

Demonstrations and on-farm trials will provide data for partial budget and marginal analysis, comparing the returns to investment of alternative technologies. Farmer evaluations will provide further insights (e.g., labour requirements for CA technologies). Household surveys will provide data on current poverty levels. Extrapolation of the experimental data will provide estimates of the impact of CA technologies on income.

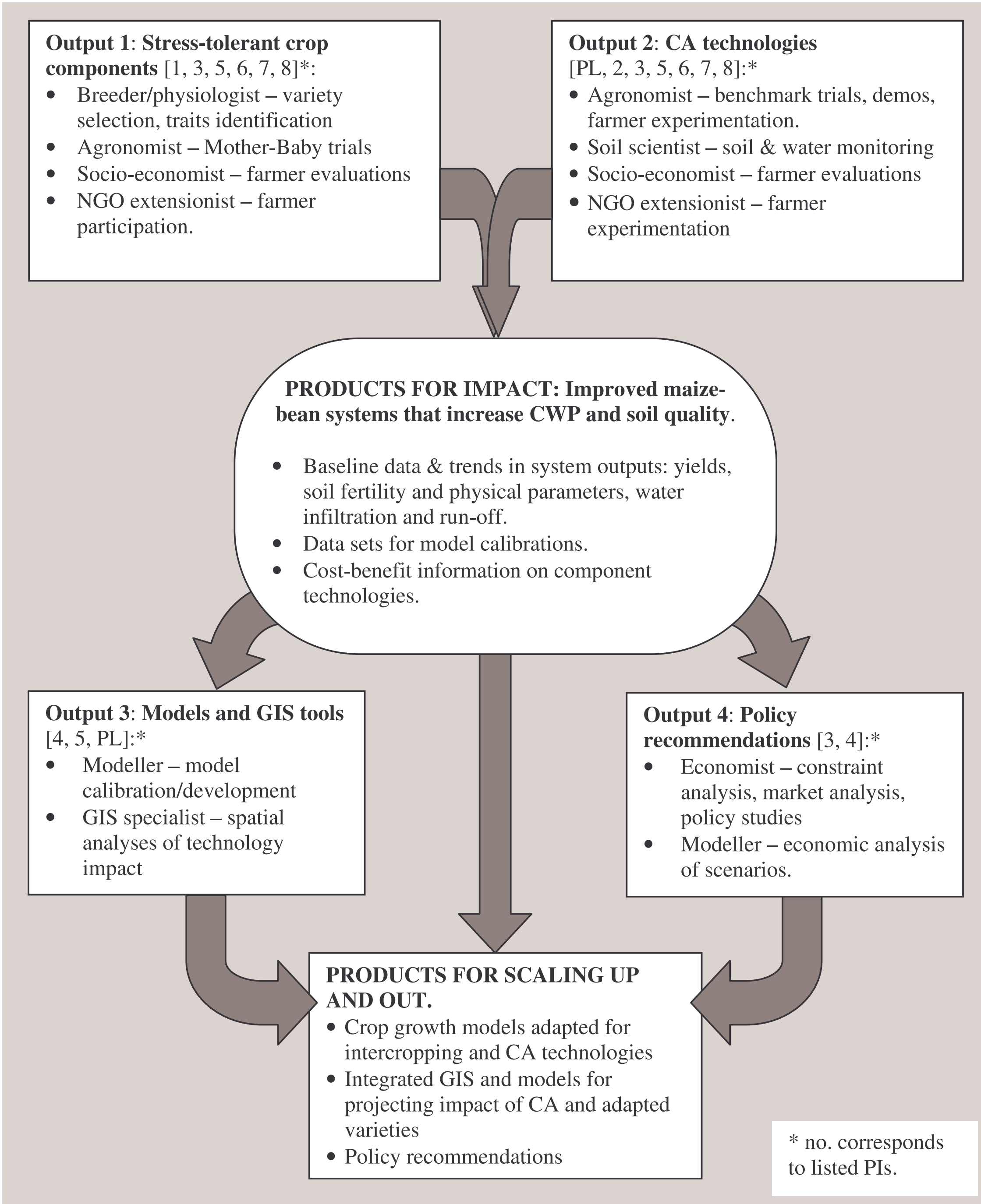
4.5 Develop policy recommendations to reduce or remove constraints to increased use of inputs and adoption of CA technologies, and assess the impact of different policies.

The impact of the technologies under different scenarios will be assessed by analyzing and extrapolating the experimental and household data. Through these scenarios, the effect of different policies and institutional arrangements on adoption, as well as on the expected changes in output and income, will be estimated for different types of farmers, by gender or endowment, and for different areas. This will assist policy makers, extension and credit providers (government or non-government), and the private sector to develop policies in function of their respective objectives.

Roles of Project Researchers and Institutions

Project activities will be organized around three sites and implemented by a 3-4 member interdisciplinary team comprising (depending on site) a breeder, soil scientist, agronomist/ physiologist, socio-economist and NGO extensionist. A team leader from among the listed PIs will coordinate day-to-day activities at each site. PIs responsible for each Output are illustrated in the diagram below. Disciplines necessary to deliver the Output are also identified together with indicated responsibilities. Additional specialists to the listed PIs are drawn from the listed participating institutions and the participants in the Kisumu project consultation meeting (Annex 1).

CIMMYT is well-placed to lead this project from its regional office in Nairobi where a team of six scientists (agronomists, breeders and economist) with extensive experience in germplasm development, cropping systems and socio-economics together implement several special-funded projects all of which provide input to that proposed here (Annex 3). Similarly, CIAT and TSBFI scientists, operating from regional offices in Kampala and Nairobi, have considerable experience in variety development and soil management supported by special projects (Annex 3). Modelling and GIS expertise from CIMMYT and IFDC headquarters will support the activities in developing Output 3. Most international scientists of the project team have known and collaborated with each other for many years and have individually developed strong collaborative ties with their NARES colleagues on the team through other projects and the networks.



Outputs

High population density, fragmented farms, low use of inputs and poor adoption of improved maize and bean varieties all contribute to the present situation of low maize and bean yields (generally 0.5-1.0 t ha^{-1} and 0.3-0.5 t ha^{-1}, respectively). Crop and land management practices result in large rainfall run-off and poor water capture and storage, contributing to periodic intra-seasonal moisture stress and yield reductions of 50% or more. Intensive cultivation with maize has resulted in widespread infestation with *Striga hermonthica* which causes yield losses valued at $37-88 M per annum in the Kenyan catchment alone. The high cost of inputs at the farm gate coupled with low prices for farm produce are disincentives to use of fertilizers, placing further limits on crop productivity. Poor adoption of new technologies is due to lack of knowledge among farmers, low use of participatory and community action approaches of testing and dissemination and an ineffective policy environment. **Outputs** of this project that will contribute to the project goal of improved food security, well-being and water quality for resource-poor farm families in the Victoria Nile catchment are:

1. Moisture stress tolerant maize and bean varieties with increased CWP and nutrient use efficiency.
2. Maize-bean production systems with increased water capture and productivity adapted and adopted with farmer participation and community action.
3. Assessments of the impact of CA and improved CWP at the field level on water quality and dynamics at the watershed and basin levels.
4. Impact assessments of, and policy recommendations for increased adoption of conservation agriculture methods, improved seed, fertilizer and pesticides in maize-bean systems.

A Logical Framework Matrix is given in Annex 4 where specific deliverable products (Indicators) are presented.

Beneficiaries and Impact

This project addresses the critical issue of food insecurity among smallholders in the Victoria Nile basin which leads them to over-exploit their natural resource base, causing soil and environmental degradation that ultimately impacts downstream users. In the short-term, adoption of drought tolerant, nutrient use efficient maize and bean varieties will increase **food security** in smallholder farming families through improved productivity of maize-bean production systems and increased yield stability through their ability to withstand the mid- and late season moisture stresses common in the area.

Adoption of CA techniques will further ameliorate moisture and fertility stress and increase yields through N derived from legumes. Minimum and no-till techniques with residue retention will reduce run-off, soil erosion and evaporative losses of soil moisture while enhancing water infiltration. By producing “more with less”, they will also increase returns on investments in inputs and encourage greater use of fertilizers. Higher and more stable maize and bean yields, improved soil fertility through adoption of legume cover crops and increased fertilizer use, and more sustainable land use through adoption of soil and water conserving practices will contribute to **poverty alleviation**, while increased maize and, especially, bean production will lead to **improved nutrition and health** among impoverished rural families.

Women farmers and female-headed households will have immediate benefits from adoption of CA technologies through reduced labour requirements for land preparation and weeding. The Lake Victoria region has been particularly affected by the HIV/AIDS pandemic which has reduced availability of labour and increased women’s share of work in farming activities.

Medium to long-term benefits of CA techniques will contribute to improved **environmental security** through improvements in soil and water quality. Rehabilitation of soil health (increased SOM, biological activity, structure and fertility) will improve the sustainability of agriculture. Rainwater conservation through reduced water run-off and erosion, and increased infiltration and percolation will lead to increased stream flows and reduced siltation, benefiting all downstream users with improved water quality.

This project will build human capacity at three levels: (1) participating researchers, extensionists and NGO personnel will gain skills and knowledge about CA technologies and the capacity to test them in participatory settings with farmers; (2) soil science and socio-economics students attached to the Nairobi, Makerere and Moi Universities will carry out M.Sc. thesis research in target areas; (3) policy makers will gain knowledge of the potential impact of stress tolerant varieties and CA technologies on farmers', community and environmental well-being, and the enabling policies that would facilitate widespread adoption. It is expected that the number and diversity of partners as well as the implementation of the project through three networks will expose a large number of NARES scientists to methodology and product development during the project and foster similar experimentation outside the project target areas.

Research in this project focuses on **Scales 2 and 3** on the CP "Pathway to impact". On-going research at CIMMYT, CIAT and the ECAMAW and ECABREN networks supported by other projects (Annex 4) has already produced deliverables at Scales 1 and 2 in the form of drought and N/P use efficient maize/bean germplasm adapted, in the case of maize, to biotic stresses in the target areas. Similarly, ECAMAW and TSBFI (AfNet) scientists have evaluated various green manures and cover crops in maize based systems while other projects have tested various CA technologies on-farm (Scale 2). This project will benefit from linkages to these on-going projects implemented by CIMMYT, CIAT and TSBFI.

Assumptions and Risks

- Only partial salaries (10-25%) of IARC staff are charged to this project. An important assumption is that the remainder will continue to be provided either through other special project funds or from core funds. International staff in the region have been successful in securing special project funding from several sources in recent years (Annex 4).
- It is assumed that NARES will maintain salaries of their staff, provide the necessary institutional infrastructure (including research facilities and vehicles) to execute project activities, and that staff turn-over will not affect continuity. The project design around small teams of NARES scientists at each site should ensure continuity should any member of the team leave the project. Availability of vehicles is often a constraint faced by NARES scientists; the project proposes to provide two pick-ups to NARES on a hire-purchase basis.
- NGOs operate on special project funding and their participation constitutes supplementary activities to their on-going programs. It is assumed that their base funding is secure and they will remain active in the target area(s) for the duration of this project. NGOs identified for this project are regional or international with reasonably secure funding.
- CIMMYT, CIAT and TSBFI-CIAT operate primarily through the ECAMAW, ECABREN and AfNet Networks which provide input to this project through linked objectives, and which provide a channel for wider dissemination of project outputs. We assume continuity of funding for the Networks.
- International regulations for germplasm exchange have become more strict but it has been possible to meet new requirements. Agreements are in place for exchange of maize and bean germplasm within the ECAMAW and ECABREN Networks. Moreover, ASARECA is developing policies for harmonizing variety release and seed regulations in the region.

Monitoring and Evaluation Plan

The PL will have overall responsibility for coordinating and monitoring project activities. He is well positioned in Nairobi to follow up with other IARC scientists, NARES and NGO partners. PIs from CIMMYT and TSBFI-CIAT are located on the ICRAF premises with the PL. CIAT's regional office in Kampala can provide local support to the bean breeding and physiology research with input from CIAT headquarters. These regional PIs will monitor activities for which their institute is responsible. Sites are easily accessible to the PL and international PIs from Nairobi and/or Kampala via local flights. Sites are within 2 hours drive of airport facilities. Telecommunications in the region of project implementation is reasonably reliable.

An initial and thereafter annual project coordination workshops will be held to develop workplans and annual budgets for each site and activity. Where possible, planning and reporting workshops will be coordinated with the annual workshops of one of the three participating networks, probably on a rotating basis. Since much of the project activities revolve around field plantings, and the bimodal rainfall distribution essentially determines the general planting dates, this also establishes a natural cycle of project monitoring for completion of tasks: planting, data taking, harvest, etc. (see Gantt Chart, Annex 2). Each PI will report briefly to the PL on trial establishment, and will deliver a formal report at the end of each crop cycle. Appropriate reporting periods to the CP would therefore be March–August (reporting in September) and September–February (reporting in March). An external evaluation would be appropriate in August of Year 3.

Dissemination Strategy

The strong orientation toward farmer participation in technology development and evaluation will contribute to the dissemination of project outputs, particularly the 'hard' products of the research (improved varieties, CA practices, etc.).

Farmer participatory evaluation of stress tolerant maize and bean varieties using Mother-Baby trials will help create an early demand for improved seed. Similarly, since the development and evaluation of CA technologies will involve farmer experimentation and community mobilization through partnership with development NGOs, dissemination in the target areas will be an integral part of the project.

Dissemination beyond the target areas will depend on the strength of the strategic partnerships developed during the project, and the involvement of the extension services at both field and managerial levels in project implementation. Participation of research and extension managers and personnel from outside the target areas in farmer field days will assist in dissemination beyond the watershed. Reports, information brochures and manuals will be prepared for dispersal to participants and the interested public. Involvement of seed companies and pesticide producers who stand to gain commercially from adoption of improved seed and CA technologies (where herbicides may find greater use) will further assist in dissemination of these technologies. The participation of CARE also opens opportunities for widespread dissemination in other regions and/or countries.

Results and recommendations from socio-economic studies will be published in reports and presented to key agricultural and environmental advisors and policy makers in the government, and science and extension managers in the NARES. Similarly, the analyses and scenarios generated by simulation models and GIS will be used to advise policy makers on the potential impact of the improved germplasm and CA technologies and assist in priority setting and technology targeting for greatest impact. Links to ECAPAPA, the regional network charged with promoting economic growth through application of growth-enhancing agricultural policies, will be used to advance recommendations through ASARECA.

Annex 1. Project Consultation Workshop, Kisumu, Kenya

A one-day workshop was organized on August 8th at Kisumu, Kenya, with potential project collaborators from the ECAMAW, ECABREN and AfNet Networks. Ten scientists from NARES and Universities in the lake region as well as three representatives from NGOs active in the region participated together with four scientists from CIMMYT and TSBFI of CIAT. The workshop discussed and reviewed the objectives, activities and outputs described in the CN, and modified them to improve applicability, feasibility and potential impact. The merits and problems of several potential project sites were listed and discussed to assist in arriving a final selection (see Table on following page). Finally, methods of diffusing technologies for impact with farmers were discussed with NGO participants.

Participants were:

1. Prof John Okalebo
   Associate Professor–Soil Chemistry,
   Fertility & Plant Nutrition
   Moi University
   Eldoret, KENYA

2. Mr. John O. Achieng', Agronomist
   KARI-Kakamega
   Kakamega, KENYA

3. Mr. Martins Odendo, Socio-economist
   KARI-Kakamega
   Kakamega, KENYA

4. Mr. Gedion Rachier, Crop Physiologist
   KARI-Kakamega
   Kakamega, KENYA

5. Dr. George Duncan Odhiambo
   Agronomist
   KARI-Kibos
   Kisumu, KENYA

6. Mr. Manase Owade Nyanjom
   Assistant Project Manager
   CARE
   Siaya, KENYA

7. Fredrick Apopa, Development worker
   CARE
   Siaya, KENYA

8. Dr. Kayuki C. Kaizzi
   Research Officer / Soil Scientist
   NARO/Kawanda-ARI
   Kampala, UGANDA

9. Mr. Drake Ssenyange, Project Coordinator
   Africa2000 Network
   Kampala, UGANDA

10. Mr. John Baptist Tumuhairwe
    Soil Scientist
    Makerere University
    Kampala, UGANDA

11. Dr. Joseph Kikafunda
    Research Agronomist
    NARO/NAARI
    Kampala, UGANDA

12. Mrs. Magdalena Magere William
    Agronomist
    ARDI-Maruku
    Bukoba, TANZANIA

13. Dr. Leonis Jonathan Ndege
    Production Ecologist/Agronomist
    ARDI-Maruku
    Bukoba, TANZANIA

14. Dr. Dennis Friesen
    Regional Maize Systems Specialist
    CIMMYT
    Nairobi, KENYA

15. Dr. Hugo De Groote
    Economist
    CIMMYT
    Nairobi, KENYA

16. Dr. Fred Kanampiu
    Agronomist
    CIMMYT
    Kisumu, KENYA

17. Dr. André Bationo
    Soil Scientist/Afnet Coordinator
    TSBF-CIAT
    Nairobi, KENYA

Project Sites Identified by NARES Participants[§]

Characteristic	Kakamega, KY	Siaya, KY*	Iganga, UG*	Masaka, UG	Nkwenda, TZ	Kyaka, TZ*
Dominant cropping systems	Maize-beans intercropping	Maize-beans intercropping	Maize-beans intercropping (80%)	Maize-beans intercropping	Banana – coffee 50%, Maize beans 50%	Maize-beans 70%, Banana –coffee 30%
Farmers with oxen	Few	Few {10 percent]	Most farmers hire oxen for plowing	None	None	None
Land preparation methods (hoe or plow)	Mostly hoe, some oxen	Mostly hoe	Hoes & Ox plows	Hoes & few use tractors	Hand hoe	Hand hoe
Soil types	Acrisols and Ferralsols	Red soils in the high lying areas to black cotton in the low lying areas	Lixic Ferralsols	Petric Plinthosols	Arenasols	Alluvium
Soil texture	Sandy loams & sandy clay loams	Loamy,Sandy	Coarse - Loamy	Loamy	Sandy loam	Clayey loam
Soil fertility status	Low to medium	Low	Low	Low	Medium	Medium
Constraints	Soil acidity Low P	Striga Intra-seasonal moisture stress Soil erosion	Moisture stress Striga Soil erosion	Moisture stress Soil erosion	Early drought Soil erosion	Mid season and Late drought
Avg. rainfall	1200-2000 mm	1250-1450 mm	750-1000 mm	800 -1000mm	750 – 1000mm	800-1300 mm depending on altitude
Rainfall distribution	Bi-modal	Bi-modal	Bi-modal	Bi-modal	Bi-modal	Bi-modal
Altitude	1600 masl	1270 masl	1200 masl	1466 masl	1450 – 1500m	1200 – 1300m
Distance from Centre	< 50 km	< 100 km	120 – 150 km	150 – 200 km	120 km	40 – 60 km
NGOs in area	Several women's groups; SCODP	CARE-Kenya	Africa2000 Network SG2000	Masaka Diocese Development Assoc. Community Enterprise Devel. Org. (CEDO)	FAO - FFS KAEMP, LVEMP	KAEMP, W Vision, FAO FFS

[§] Sites identified with an asterisk (*) are the preferred sites in each country.

Annex 3: Recent and on-going special projects implemented by CIMMYT and CIAT in ECA

PROJECT	DONOR(S)[4]	DURATION	STARTING DATE	ENDING DATE	TOTAL BUDGET (USD)
CIMMYT MAIZE PROJECTS					
Developing and Disseminating Stress Tolerant Maize for Sustainable Food Security in West, Central and East Africa	UNDP, Sida, IFAD BMZ RF	36 36 36	Jan 1998 Jan 2002 Jul 2002	Dec 2000 Dec 2004 Jun 2004	1,217,000 1,300,000 480,000
The Insect Resistant Maize for Africa Project	Syngenta (Novartis) Foundation	48	Oct 1999	Sep 2003	
Engineering Striga-Resistant Maize	RF	36 (Phase I) 36 (Phase II) 24 (Phase III)	Jan 1997 Jan 2000 Jan 2003	Dec 1999 Dec 2002 Dec 2004	-- 438,000 460,000
Developing and extending methodologies for controlling Striga in western Kenya	BMZ/GTZ	36 (Phase I) 24 (Phase II)	Jul 1995 Jul 1998	Jun 1998 Jun 2000	354,000 258,000
Development and diffusion of integrated Striga control practices for small-scale farmers in western Kenya	PRGA-NRM (CIAT)	35	Jan 1999	Nov 2001	300,000
Strengthening Maize Seed Supply Systems for Small-Scale Farmers in Western Kenya and Uganda	RF	36 (Phase I)	Jul 2001	Jun 2003	427,000
East Africa Cereals Program	CIDA	34 (Phase I) 49 (Phase II) 49 (Phase III) 80 (Phase IV with extensions)	Jul 1985 May 1988 Jun 1992 Jul 1996	Apr 1988 May 1992 Jul 1996 Mar 2003	-- -- -- 3,263,000
Quality Protein Maize Development and Dissemination	CIDA	60	Jan 2003	Dec 2007	3,100,000
Development and Promotion of Quality Protein Maize in Sub-Saharan Africa	Nippon Foundation	60	Apr 2002	Mar 2006	3,282,000

[4] UNDP=United Nations Development Program; Sida=Swedish International Development Agency; IFAD=International Fund for Agricultural Development; RF=Rockefeller Foundation; BMZ/GTZ= German Agency for Technical Cooperation; PRGA-NRM= CGIAR Program on Participatory Research and Gender Analysis–Natural Resource Management; CIDA=Canadian International Development Agency; SDC= Swiss Agency for Development Cooperation; USAID= United States Agency for International Development

PROJECT	DONOR(S)[4]	DURATION	STARTING DATE	ENDING DATE	TOTAL BUDGET (USD)
Improving the Yield and Nutritional Value of Popular Maize Cultivars for Resource-Poor Farming Families in Eastern and Southern Africa	RF	36	Sep 2002	Aug 2005	---
Facilitating the widespread adoption of conservation agriculture (CA) in maize-based systems in Eastern and Southern Africa (ESA)	BMZ/GTZ (under review; approval pending)	36	Jan 2004	Dec 2006	1,600,000
CIAT BEAN PROJECTS					
PABRA: Rural Poverty Alleviation in Africa.	CIDA	29	03/11/2000	31/03/2003 (extension approved)	1,274,000
Eastern and Central African Bean Research Network (ECABREN) and the Southern Africa Bean Research Network (SABRN).	SDC	36	Sep 2001	Sep 2004	1,735,000
Strengthening Urban Agriculture in Kampala, Uganda	Centro Internacional de la Papa (CIP)	12	Jul 2002	Jun 2003	20,850
Assisting disaster-affected and chronically stressed communities in East and Central Africa: focus on small farmer seed systems.	USAID	12	Mar 2002	Feb 2003	245,650
Increasing Food Security and Rural Incomes in Eastern, Central and Southern Africa through Genetic Improvement of Bush and Climbing Beans.	RF	36	Jan 2001	Dec 2003 (extension in process)	449,000
An integrated approach for genetic improvement of aluminium resistance of crops on low-fertility acid soils	BMZ/GTZ	36	Jan 2001	Dec 2003	166,500
Crop Biofortification Initiative	USAID	6	Jan 2002	Dec 2004	600,000
Crop Biofortification Challenge Program	World Bank and Gates Foundation	48	Jan 2003	Dec 2008	2,101,000

Annex 4: Logical Framework – Increasing Crop Water Productivity in the Victoria Nile Basin Using Stress Tolerant Maize and Bean Varieties in Conservation Agriculture Systems

Overall goal	**Indicator(s)**	**Means of Verification**	**Assumption(s) and risks**
Improved food security, well-being and water quality for resource poor smallholder farmers in the Victoria Nile catchment through more water efficient agriculture based on drought tolerant and nutrient use efficient maize and bean cultivars, conservation agriculture techniques, and enhanced soil fertility.	• Increased maize and bean production with improved maize and bean cultivars and conservation agricultural practices that improve crop water productivity and water quality in the Lake Victoria catchment of the upper Nile basin. • Improved food security • Improved crop stability • Improved livelihoods	• Maize and bean production statistics in the target region • Crop water productivity in the target region • Water and soil quality in the target region • Adoption statistics of maize-bean systems	• Adoption continues at least at rates comparable to those in the past
Purpose	**Indicator(s)**	**Means of Verification**	**Assumption(s) and risks**
To improve food security and downstream water quality through integrated use of improved cultivars, conservation agriculture (CA); and soil fertility	• Smallholders, Regional Networks, NARES and NGOs use improved maize and bean cultivars and conservation practices on 25% of the target area by the year 2008.	• Reports of Regional Networks, NARES and NGOs • National statistics • Publications	• Continued donor support to Regional Networks
Outputs	**Indicators**	**Means of Verification**	**Assumptions and risks**
1 Moisture stress tolerant maize and bean varieties with increased CWP and nutrient use efficiency.	• Adapted maize hybrids and OPVs that yield 50% more than current farmer varieties under low soil N and/or mid-season moisture stress conditions • Knowledge of roles of different plant traits in determining plant adaptation to moisture and nutrient stress • Drought & low-P tolerant bean varieties resistant to ALS, BSM &/or root rots • Bean varieties with adaptation to maize-bean intercropping systems.	• Annual reports • Reports of variety release committees • Publications • Field performance of system components	• Drought adapted genotypes combine well with biotic resistant genotypes • Nutrient efficiency combines well with improved crop water productivity
2 Maize-bean production systems with increased water capture and productivity adapted and adopted with farmer participation and community action.	• Increased water infiltration and reduced run-off from maize-bean fields • Improved soil quality (SOM content, structure, fertility, biological activity) • Knowledge and use of CA practices among farmers in target areas. • Community-based organizations functional in target areas and active in testing and disseminating CA practices and improved maize and bean varieties.	• Progress reports on benchmark trials and results; syntheses of farmer evaluations. • Report on identified farmers' groups, their composition and purpose and mode of function. • Databases and progress reports.	• Farmers can be organized for concerted community-level adoption of varieties & CA technologies • Seed of improved varieties available in each country • Socio-economic & policy constraints to increased fertilizer use are resolved.
3 Assessments of the impact CA and improved crop water productivity at the field level on water quality and dynamics at the watershed and basin level.	• Improved models adapted for intercrop maize-bean and CA systems. • GIS analysis tool constructed for interpreting spatial data. • Linked GIS and model decision support tool for scenario analysis. • Identification of areas with maximum potential for improved crop water productivity for a range of CA technologies and improved cultivars.	• Reports validating adapted model performance against measured data from field experiments. • GIS database & spatially referenced simulation model outputs available in simple decision support tool. • Electronic & conventional publications of spatial & temporal simulation studies showing projected impact	• Data dissemination not limited by restrictive IPR issues. • Spatial data is of sufficient quality and resolution to permit accurate predictions.
4 Impact assessment & policy recommendations for increased adoption of CA methods, improved stress tolerant varieties, & inputs in maize-bean systems.	• Policy briefs showing scenarios for protection of lake basin. • Essential institutions identified and recommendations formulated to improve their functioning • Policies identified to make inputs prices affordable by resource poor smallholders.	• Reports on PRAs and household surveys • Published policy briefs • Impact assessment model to quantify the effect of different policies on farmers' income	•

Activities (coded by Objective/Output)	Milestones
1.1 Evaluate drought tolerant, N-use efficient maize varieties with resistance to local biotic stresses in on-farm trials with farmer participation	• At least 4 Mother-Baby trials established in each target area in each of the first 3 years. • At least 2 improved stress tolerant hybrids and OPVs nominated for release in each target country.
1.2 Select and evaluate drought tolerant, P-use efficient bean varieties with resistance to Angular Leaf Spot (ALS), root rots and/or Bean Stem Maggot (BSM).	• At least 5 genotypes with multiple stress resistance selected & evaluated using 4 Mother-Baby trials established in each target area in each of the first 3 years. • At least 2 adapted multiple stress tolerant lines with improved CWP nominated for release in each target country.
1.3 Determine genotype x environment interactions of drought tolerant and nutrient use efficient genotypes under different water and nutritional regimes, and the roles of different plant traits in sub-optimal environments.	• Researcher managed trials established at benchmark sites. • Critical plant traits for multiple stress environments defined as objectives for breeding programs.
1.4 Demonstrate and disseminate maize and bean varieties adapted to local agro-ecological conditions and stresses.	• Farmer field days held at Mother trials • Mother-Baby trial results reports prepared for national variety release committees
2.1 Evaluate and adapt CA technologies to local maize-bean systems.	• Baseline information of current farmer practices, maize-bean cropping systems available • Recommendation domains defined for each target area. • Researcher managed trials to test CA components established at each benchmark site
2.2 Identify and/or organize farmer groups for mobilization and training in group dynamics and community organization to facilitate community adoption of CA technologies.	• Directory of farmers' groups compiled or, if none present, farmers' groups organized in each target area. • Training courses conducted for researchers, extensionists, NGOs and farmers on CA component technologies.
2.3 Facilitate adaptation and adoption of CA technologies through pilot demonstrations and farmer experimentation in target areas.	• Field day conducted at benchmark sites for farmer exposure/training in CA technology components. • Farmer managed CA demonstration trials established in target areas.
2.4 Determine the effects of CA technologies on water infiltration, storage and run-off, and soil erosion and quality.	• Baseline soil quality measurements (SOM, structure, infiltration rates, penetrability, etc) conducted in all systems in researcher managed trials at each benchmark site and in farmer managed demonstrations. • Soil quality measurements conducted in benchmark trials and farmer demonstrations each year at each site.
2.5 Determine the effects of CA techniques on crop development and productivity, and monitor their effects on crop pests and pathogens.	• Measurements of maize and bean productivity under different farmers' practices and CA technologies in benchmark trials and demonstrations. • Information on the incidence and numbers of crop pests and diseases under different systems.
3.1 Develop data for parameterization and calibration of crop growth models for local soil types, climatic conditions and CA practices.	• Data from well-documented field experiments assembled in appropriate formats. • Maize and bean models calibrated (genetic coefficients determined) for locally adapted cultivars.
3.2 Develop and test subroutines to improve model sensitivity to maize-bean intercrop systems and soil management practices identified with CA technologies (residue retention, minimum tillage, etc.).	• Subroutines incorporated for simulating maize and bean grown as intercrops. • Subroutines incorporated for simulating water and N,P dynamics as influenced by surface residue and tillage.
3.3 Acquire spatial data of watershed soils, topography and hydrology to scale up plot and field-scale model simulations and organize these together with plot and community data into a GIS.	• Report on available spatial data • Available spatial data compiled into a spatial database. • Spatial database incorporated into a GIS analysis tool.
3.4 Combine spatial data and plot-level simulations in a GIS to develop predictions of the impact of CA, stress-adapted varieties and soil fertility improvement on water use and dynamics in the watershed.	• Spatial data assembled into format required by simulation models. • Scenarios developed and analyzed together with stakeholders.
4.1 Conduct socio-economic and gender analyses to estimate demand for CA technologies and determine constraints to their adoption.	• PRA reports with selection criteria for new technologies, preferences for established technologies, and constraints, all gender-disaggregated • Report on household surveys with current levels of adoption of improved technologies
4.2 Analyze input/output markets to determine their effects on adoption of CA technologies.	• Report on marketing of inputs and outputs, based on analysis of secondary data and interviews of key informants
4.3 Analyze the institutional framework in which farmers operate, determine its constraints and identify mean to overcome constraints to enhance adoption of CA, improved varieties and inputs.	• Report on the institutional analysis, based on visits to the key institutions, group discussions with farmers, and key informants
4.4 Assess the potential impact of CA technologies on farmers' income and rural poverty.	• Ex ante impact assessment report • Quantification of the potential impact on yield and income, at the farm, community and regional level
4.5 Develop policy recommendations to reduce or remove constraints to increased use of inputs and the adoption of CA technologies, and assess the impact of different policies.	• Policy briefs and reports analyzing and comparing alternative policies and their likely impact

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