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List of Acronyms

CERES	Clouds and the Earth's Radiant Energy System
DSSAT	Decision Support System for Agrotechnology Transfer
FEWS NET	USAID Famine Early Warning Network
FSG	MSU Food Security Group
FTF	Feed the Future
GCM	Global Climate Model
NOAA	National Oceanic and Atmospheric Administration
RFE	African Rainfall Estimation Algorithm
USAID	United States Agency for International Development

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Technical Application

Associate Award Application under Food Security III Leader Award CDG-A-00-02-00021-00

Improved Modeling of Household Food Security Decision Making and Investments Given Climate Change Uncertainty

<u>Program Description</u>

Introduction

The activities proposed for implementation under this associate award will contribute directly to the goals of the Feed the Future (FTF) initiative. FTF focuses on sustainable reductions in hunger and poverty, with two key objectives: "accelerating inclusive agriculture sector growth and improving nutritional status" (FTF 2010, v). Climate change is recognized as a cross-cutting issue to be considered in designing programs to address FTF goals. The FTF Guide recommends that assessment of climate risk should be incorporated into food security efforts, stating: "Ensuring a sustainable and resilient agricultural development strategy requires countries to understand the potential implications of current and anticipated climate risks and vulnerabilities on the strategic objectives of their food security programs" (FTF 2010, 30-31).

Relatedly, the FTF Global Food Security Research Strategy notes that "advances in modeling of climates, production systems and actual or potential threats (e.g. pathogens, drought) can help guide research investments." (FTF 2011, 38). In addition, Zambia and Kenya include significant areas that fall into two of the Research Strategy's priority production systems, namely maize-based production systems in Southern and Eastern Africa and the East Africa highland system in which maize is also important. Regarding the former system, the Research Strategy notes that "maize is the defining crop for millions of food-insecure smallholders," and that "sustainable intensification equates with improving resilience in the face of frequent drought through improving soil moisture holding capacity and diversification for both fertility and income growth" (FTF 2011, 31)

Background

An increasingly important limiting factor for increased food production in Africa and Asia is climate, particularly low or erratic precipitation. Efforts to increase food production need to consider expected changes in climate as they affect agricultural productivity. These changes will affect high productivity zones, availability and access to food in neighboring deficit zones, as well as regional trade patterns. Efforts to develop agricultural responses resilient to climatic changes are limited by a lack of information on current and future environmental limitations, particularly at the sub-national level, and on their likely impacts on household food security.

Coupled climate, crop, land use and surface water simulation models can allow realistic analyses of the direct and interactive impacts of climate, soils and technological factors on crop production at a small fraction of the staff, financial and time requirements associated with standard field-level research. Nationally representative farm household survey data can provide the basis for modeling household production and income-earning activities in major agroecological zones, and for evaluating the impact of climate and weather factors on household food security outcomes.

Michigan State University has two groups of faculty members and researchers whose work relates to the above topics. First, a group of geographers and agro-climatologists has a regional climate-land modeling framework calibrated for East Africa that explores current and future effects of climate and management factors on crop production. Second, the MSU Food Security Group, consisting of nearly 20 faculty members based on campus and in the field, carries out a number of projects related to food security, of which the most significant is the Food Security III Cooperative Agreement. FSG projects in eastern and southern Africa have included support for multiple years of nationally representative farm household surveys, collected by the Central Statistical Office in Zambia and by the Tegemeo Institute and the Central Bureau of statistics in Kenya. These surveys include panels of the same households covering three different years in Zambia (with a fourth panel wave planned in 2012) and five different years in Kenya. Years and sample sizes are shown in Table 1. A map of the survey coverage in Zambia is in Annex F.

Table 1. National Farm Household Panel Surveys in Zambia and Kenya

Zambia		**Kenya**	
Year	**Sample Size**	**Year**	**Sample Size**
2001	6,922	1997	1,581
2004	5,421	2000	1,422
2008	8,094	2004	1,372
2012	(coming mid-2012)	2007	1,266
		2010	1,850

The East Africa regional modeling framework generates mapped results at the 18 x 18 kilometer scale, and site-level, higher-resolution results at the 6 kilometer scale. Climate data coupled to a process-based crop model can identify the effects of climate, climate variability and management practices such as fertilizer use, crop variety and planting dates on yields of rice, maize and other crops. The climate model coupled to a surface water model can provide information on the impact of climate change on water availability for human consumption, irrigation, or electricity generation. The model results can inform decisions on what crop varieties and management practices would be the most productive under current and projected future climate change. It can also provide information on the impact of climate change and variability on the amount of production available for household food security and trade. This type of modeling analysis can therefore directly support the value chain development objectives addressed by USAID.

In addition to modeling future crop productivity and water availability, analysis of historical data (remote sensing and meteorological station data) can provide information on climate trends from the 1960s to present, and their impact on maize and rice productivity. Critical questions being asked by governments, such as how rainy seasons are changing in length, start date, and reliability, or whether droughts are becoming more frequency and severe, can be examined.

There are several different potential approaches to defining the onset and cessation of the rainy season. For onset there are two potential approaches we are likely to use:

(1) Onset = first four rainfall events of 10 mm or more with no 7-day dry spell between any two such rainfalls. The reverse would be the cessation of the rainy season. Or,

(2) from Liebmann et al. (2007), using a formula for accumulated rainfall: Where the rainy season is the longest period for which anomalous accumulation remains greater than the annual mean accumulation. This would also define the cessation point. For reliability, each station has data for a reliability function based on rainfall probability as outlined in Tshecko (2004).

The research and the policy-making process is being informed by engagement with rural communities to learn of their strategies for responding to current and expected climate change. Ecodym will be engaging with rural communities in Kenya through focus group discussions. MSU will hire local consultants to conduct focus group discussions in Zambia. Such information can inform the experimental design and the interpretations of modeling results, and results in more realistic and effective adaptation mechanisms.

MSU's Food Security Research Project (FSRP) in Zambia, funded for 2010-2015 by USAID and SIDA, will include nationally representative household data collection and food policy analysis that supports the goals of FTF and the Comprehensive African Agriculture Programme (CAADP). Climate change research by University of Zambia faculty and collaborators will be supported under the FSRP competitive grants program, and will focus on identifying farm household coping and adaptation strategies in response to climate change. The household-level economic modeling proposed for this Award will provide information on the impact of potential FTF project interventions and of climate variability on different household wealth categories, and support economic, nutrition and food security impact analysis of project interventions and climate change.

Purpose of Award

The purpose of the activities supported under this Award is to link the multiple-year household survey datasets available to MSU, and MSU's coupled climate, crop, land use, and water availability models, in order to improve understanding about how rural households are adapting to climate change (in terms of agricultural production practices and technologies, and perhaps other income-earning strategies), and about the impacts of anticipated future climate scenarios on farm household production, income, and food security. This information will help refine the climate change models and estimates of future household technology adoption and investment decisions, with implications for country program and policy priorities.

Proposed Activities

Briefly summarized, the proposed activities are as follows. The work will be carried out in two pilot countries, Zambia and Kenya, with Zambia activities beginning in Year 1 and Kenya activities beginning in Year 2.

1. Historical analysis of rainfall patterns over space and time using weather station data and a new promising Africa-wide data source, African Rainfall Estimation Algorithm (RFE). RFE and the Rainfall Estimation Algorithm refer to the same thing. RFE is the acronym for the operational product (daily precip. estimates across the African continent at 0.1 deg. spatial

resolution), which is based on version 2.0 of the algorithm implemented in 2001. Data are currently available back to 2001 but efforts are underway to extend the data series back to 1982. Data are available via ftp at ftp.cpc.ncep.noaa.gov/fews/newalgo_est/ Nick Novella (Nicholas.Novella@noaa.gov) is the primary NOAA contact for this program.

2. Analysis of impact of past climate variability and trend changes on maize yields, using climate-crop models, and on indicators of household well-being such as food security and income, using the multiple-year household data. As a comprehensive, dynamic crop model, DSSAT simulates crop growth and productivity on a daily or more frequent basis and directly links the effects of water supply on plant growth and development. Maize, for example, is very sensitive to a short dry period during its flowering stage. DSSAT should better reflect the overall impact of precipitation amounts and timing during the growing season than the Water Resource Satisfaction Index (WRSI) model, which is based on the mass water balance approach. Dynamic crop growth during the season is not explicitly accounted for in WRSI.
3. Projection of future climate scenarios and their impacts on maize yield and output. The results of downscaled GCMs and linked crop modeling will be georeferenced. The output will be in the form of maps and data (e.g., maps of change in temperature, precipitation during growing season, change in maize yields, etc.). The scale of analysis is flexible; we have been using 6 km for the high-resolution, localized analyses.
4. Construction of farm household models, and incorporation into those models of projected future climate change and maize yield scenarios in order to identify impacts on future household production, farm and off-farm incomes, and food security. The result will be a prototype model that would provide household-to national-level information on impacts of recent and future climate change and variability (see Table 2).
5. Use of focus groups to guide the design and interpretation of (1) and (2), and feedback groups to discuss the outcomes of (3) and (4).
6. Outreach to key stakeholders in the pilot countries and in the U.S.

Table 2. Inputs to Prototype Model Linking Household Survey, and Crop-Climate Data and Models to Identify Household Decisions in the Context of Climate Change and Variability.

	Households	Crop Production (yields)	Climate
Recent (1980s to 2010)	Model impact of climate variability, household decisions in the context of climate variability, and how varies by household characteristics; responses to climate variability or change. Data available: panel household survey data with geographic coverage of the country, community interviews.	Model crop yields in a GIS framework for the entire country using a process-based crop model[1] for the same time periods as the household survey data to identify effects of spatial variability, management factors and particularly weather (data from weather stations, RFE) on yields.	Analyze weather station data and RFE data to provide input to crop-climate model, and to identify temporal and spatial trends in climate (temps, precip), climatic extremes (drought) and rainy seasons.
Linkage processes between systems[2]	Crop production, income and food security as affected by weather, management and household factors.	Simulated crop yields as affected by weather data, simulated management factors	Daily and monthly weather during survey years, and climate trends over space and time.
Simulations of 2000- 2050	Household modeling to identify possible impact of future climate and crop yields on households, their decisions in response, and effectiveness of potential adaptation measures.	Crop-climate model informed by climate simulations to produce expected impacts of climate change on future crop yields	Climate simulations with four Global Climate Models to produce changes in temps, precipitation patterns over space and time.

Further Details on Proposed Activities (Illustrated for Zambia Case)

Activity 1.Analysis of changes in rainfall patterns.

Statistical analysis to identify trends in precipitation using meteorological (weather) station data and the African Rainfall Estimation Algorithm RFE 2.0 gridded (GIS) 1982-2010 climate database (Love et al. 2004). The analyses will identify changes in:

a. Frequency, length and severity of droughts;
b. Changes in amounts and timing of rainfall
c. Growing season precipitation totals, and variability between years;
d. Onset, end and duration of rainy seasons.

[1] A process-based crop model is a model developed and structured on the individual and interactive physiological processes governing plant growth, development, and productivity.
[2] The linkage process between systems represents the variables that are common to the household agricultural system, crop production, and climate. An example could be precipitation amounts and variability, which emanate from the climate system and affect crop production, and thus household food security.

Activity 2.The impact of climate variability and change on maize yields.

Identify the impact of changes in rainfall variability on maize yields (e.g., breaks in rainfall during the rainy season) by running the DSSAT CERES maize model informed by weather station and RFE data, and agricultural statistics and other GIS data. This will add to the recent global analysis by Lobell et al. (2011), and the analysis of Zambia's 2009 and 2010 maize production by Burke et al. (2010).

a. Construct maps of annual maize yield (kg/ha) and changes in maize yields for Zambia from 1982 to 2010 by running the DSSAT maize model with the African Rainfall Estimation Algorithm (RFE) version 2.0 (Love et al., 2004), provided by NOAA as part of the USAID Famine Early Warning Network (FEWS NET). This dataset provides daily rainfall estimates at a 0.1° latitude (about 11 km) spatial resolution across Africa. While much of the variability in yield can be associated with precipitation patterns, some is also associated with sociocultural economic factors such as the level and type of crop management strategy. These factors and their impact on crop productivity can be accounted for in dynamic models. In addition, other socioeconomic factors affecting crop management and yields, such as labor ability, farm size and level of income, will be included in the household models.
b. With the DSSAT model, compare the yield effects of crop management decisions such as fertilizer application, under different climatic and soil conditions within Zambia.
c. Calculate potential national maize production under different climatic and management conditions, assuming no change in marketing conditions or maize area cultivated, including improved varieties such as the drought-tolerant maize for Africa varieties currently promoted under HarvestPlus

Activity 3. Effect of climate variability on household food security.

Climate variability impacts on household food security are expected to be a function of the type of farming system, location, wealth, and gender of household head. An econometric analysis of household survey data will be conducted to identify how climate variability since 1990 has affected farm crop production and household food security across Zambia, and how household factors such as wealth, agricultural technologies practiced and gender of head of household have affected their vulnerability or resilience to climate. Survey and modeling results will be shared with surveyed communities in gender-disaggregated focus groups, to obtain their feedback on study results and to discuss possible adaptation strategies.

Activity 4. Farm household modeling taking into account projected climate and maize yield scenarios.

This will involve two subactivities:

a. Construction of farm household models for key farm household categories. "Key categories" will be defined through a combination of criteria including vulnerability to climate change, significance in terms of national production, and food economy zoning differences that take into account ways that households obtain food other than from own production. Models will include the principal household production and income-earning activities and resource constraints, drawing on data from nationally representative household surveys and from the supplementary survey. The latter is expected to focus on identifying crop-specific input levels, since the existing survey data report input use at the household level.

b. Use of the models to identify optimal patterns of crop production and other income-earning activities—and their implications for household food security and income—given available resources and other constraints, taking into account crop yield projections derived from the climate-crop models. Alternative ways to incorporate risk into the model farmer's decision making will be explored, including those studied under the AMA BASIS CRSP. Scenarios incorporating policy changes, e.g., liberalized trade, can also be examined.

In Kenya, the project will collaborate with the government's Kenya Agricultural Research Institute's Climate Change Unit and the firm Ecodym. While Ecodym will handle the bulk of the work, we expect that KARI will participate in the community workshops, in interpretation and write-up of the results of the modeling, and in the dissemination of the research results and implications for adaptation practices and programs.

Anticipated Results

Output of these analyses will serve as:

a. A base reference for development of national- and local-level strategies for adaptation to increasing climate variability and climate change;
b. Information to plan for future variability in agricultural production and commodity trade due to climate and crop management factors such as fertilizer application rates.
c. Prototype model linking household food security to crop-climate and climate data and simulations to identify household decision making in the face of climate change and variability.

Reports and presentations at USAID/Washington and at USAID Missions in Zambia and Kenya will disseminate project findings, including:

a. Recent trends in precipitation levels and variability in different areas of the two countries.
b. Estimated effects of climate change on maize yields from 1982-2010, and the potential impact of fertilizer application on yields under various conditions, with maps of the results.
c. Identification of key components and indicators of household food security, and the importance of climate variables relative to other factors, in different zones.
d. Identification of promising strategies to mitigate or adapt to anticipated climate change.
e. Effect of climate variability and maize yield trends on food security indicators, on the activities and welfare of women relative to men, on the adequacy of national production relative to consumption requirements, and on maize imports and exports.

Management Procedures

As an Associate Award to the Food Security III Leader Award, proposed activities will be managed through the on-campus office of FS III using the same implementation arrangements and procedures as in the Leader Award. Because MSU has an existing Associate Award in Zambia, which is proposed as a pilot country under this Associate Award, close attention will be paid to ensuring that the work plans and budgets of each Associate Award are clearly distinguished. The work plan and budget proposed in this submission have been prepared with this in mind, but any needed revisions can considered prior to approval of the work plan for the project proposed here.

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Annex A

Gender Analysis and Integration

It is often recognized that the poor and marginalized groups—often disproportionately women and girls—will experience the impacts of climate change most acutely, yet they will have the least capacity to adapt (Demetriades and Esplen 2009). A large knowledge gap exists in Africa on the gender impacts of climate change, and what adaptation strategies would be successful, where, and for whom. The goal of the gender component of this project is to reduce this gap by providing information on the specific vulnerability of women and other groups to climate change impacts, and to inform policies and projects to reduce these vulnerabilities. At the project level, the framework developed by USAID for planning adaptation to climate change projects (USAID 2007) could provide a useful approach. As noted in a recent review of gender, agriculture and climate change (Olson et al. 2010), there is an unmet need to incorporate gender dimensions into climate change program planning. Most climate change-related programs do not explicitly address gender issues, but since their implementation can potentially exacerbate existing inequalities, program success may depend on addressing such gender issues.

The nexus of vulnerable locations and vulnerable groups requires particular attention at the sub-national and household levels. Climate change responses will need to be multiple and locally specific. Climate change in Zambia and Kenya is expected to affect resource-poor households unable to invest in or take advantage of alternative income sources or new agricultural strategies, and less able to recover following droughts, floods or other shocks. Communities in marginal areas dependent on rainfed agriculture will be especially vulnerable; more frequent crop failures may be the tipping point that causes them to fall below the food security threshold. Because of rural women's roles in providing natural resource and agricultural products to support family wellbeing, they will be particularly negatively affected by declining availability of water, fuelwood, livestock fodder and other natural resources, and declining crop yields. The impacts of climate change in Zambia and Kenya that have a gender dimension could thus include:

1. Increased international trade in agricultural commodities due to more frequent or severe droughts and floods affecting localized areas, and to declining or shifting production. This has implications for crop choice. If the choice tilts towards cash crops considered to be men's (e.g., hybrid maize), women may lose land available for their crops and be expected to work on the man's crop, potentially reducing food and income available for woman and children.
2. Reduced availability but higher demand for water and other natural resources during "normal" rainfall years and particularly during droughts, which is likely to increase the time spent by women in collecting these resources.
3. Out-migration of men and dislocation of families during droughts, which can lead to more permanent family break-up and an increase in number of women-headed households with attendant loss of land and labor

Climate change impacts can thus increase demand for women's labor, and reduce the income and food security of women-headed and other resource-poor households (Olson et al. 2010).

The contribution of this project is that it will be able to conduct intra- and inter-household level analyses. The project will conduct gender, wealth category and regional analyses of the household survey data. It will compare women- and men-headed households in terms of the impacts of climate on food security and income, and the ability of households to adopt and invest in climate change response strategies and in income-generating activities. The project will complement statistical analyses and modeling with gender-disaggregated focus group feedback sessions to correct and amplify our understanding of the impacts of climate change, and to discuss possible adaptation strategies.

Annex B

Life-of-Project Implementation Timeline

Year 1 (FY 2012—Oct. 1, 2011, through Sept. 30, 2012)

- Confirmation of choice of Zambia as pilot country for testing and refining the combined household and climate-crop models.
- Formation of a consortium of research entities, including individuals and organizations, with whom the MSU team will collaborate in implementing project activities.
- Meet with local universities and agricultural research institutions involved in climate change to discuss joint research activities.
- Design and implementation of project-related data collection, including secondary data and supplementary gender-disaggregated farm household data and community-level climate impact information needed for the household model for Zambia.
- Statistical and GIS analyses of weather station and African Rainfall Estimation Algorithm (RFE) satellite data for Zambia to identify historical trends and to geo-link to household data
- Climate model selection, downscaling and incorporating land surface data for Zambia
- Calibration of the crop-climate model for Zambia
- Initial design of the household model, and procedures for linking it to the climate-crop models.
- Discussions with potential collaborators in second country for model testing (expected to be Kenya)
- Initial use of the prototype model by the end of Year 1.
- Outreach on project progress in Zambia and in Washington, D.C.

Year 2 (FY 2013)

- Refinement of the prototype model for Zambia.
- Implementation of principal research activities for Zambia, including (1) analysis of historical relationship between climate/weather variability and household food security outcomes, including differential impacts on household wealth groups, (2) modeling crop yields using the crop-climate model for years of household survey, (3) simulation of projected future trends in climate, crop yields, and household food security outcomes, (4) conducting feedback workshops with men and women in communities to share project results, their experiences with the impact of climate change and variability, and possible adaptation approaches, and (5) estimation of larger-scale (e.g., national) impacts.
- Initial development of second country model in Kenya, including evaluating and collecting available secondary data (agricultural statistics, GIS, weather station) and conducting community workshops of men and women to obtain information for the household model on impacts of recent climate variability and they responded.
- Analyses of Kenya weather station data with same statistical and GIS approach as for Zambia, and conducting crop-climate modeling for Kenya to obtain results to link to household model
- Outreach on project progress in Zambia, Kenya, and in Washington, D.C.

Year 3 (FY 2014)

- Design and refinement of the household model in Kenya, and procedures for linking it to the climate-crop models.
- Implementation of principal research activities, including (1) estimating variations in recent and future crop yields using the crop-climate model, and climate using weather station data and regional climate model and downscaling techniques, (2) simulation of projected future trends in climate, crop yields, and household food security outcomes, (3) conducting feedback workshops in communities to share project results and possible adaptation approaches, and (4) estimation of larger-scale (e.g., national) impacts.
- Outreach on project progress in Zambia, Kenya, and Washington, D.C.
- Completion of project reports.

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Annex C: Work Plan for Year 1 (FY 2012)

Technical Application for Associate Award Under Food Security III Leader Award, CDG-A-00-02-00021-00													
Year 1 Work Plan		2011							2012				
Activity	**Oct**	**Nov**	**Dec**		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
1. Initial contacts with USAID and consortium members													
2. Revision and approval of work plan													
3. Travel to Zambia to initiate research activities													
4. Compile and evaluate existing Zambia weather data													
5. Calibration of crop-climate model													
6. Initiate collection of data to supplement existing surveys:													
a. Cost and price data													
b. Crop-specific production input use													
c. Gender-disaggregated focus groups on climate trends and adaptation measures													
7. Analysis of Zambia weather station and African Rainfall Estimation Algorithm (RFE) data													
8. Planning of Gender analysis and integration design													
9.. Conduct crop-climate modeling													
10.. Initial design of household models													
11. Design of procedures to link climate-crop-household models													
12. Downscale and calibrate general climate models for future scenarios for Zambia													
13. Testing/initial use of models													
14. Outreach on project progress in Zambia and Washington, D.C.													
14. Review discussions, budgeting and work plan for Year 2													

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Annex D

Names and Affiliations of Key Individuals

Personnel affiliated with Michigan State University:

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Annex E

Initial Environment Examination (IEE)

Per USAID Environmental Procedures, certain classes of actions may qualify for a Categorical Exclusion, pursuant to 22 CFR Section 216.2(c)(2), for which an Initial Environmental Examination or an Environmental Assessment is not required. The Request for Categorical Exclusion applies to all activities under the Food Security III Cooperative Agreement.

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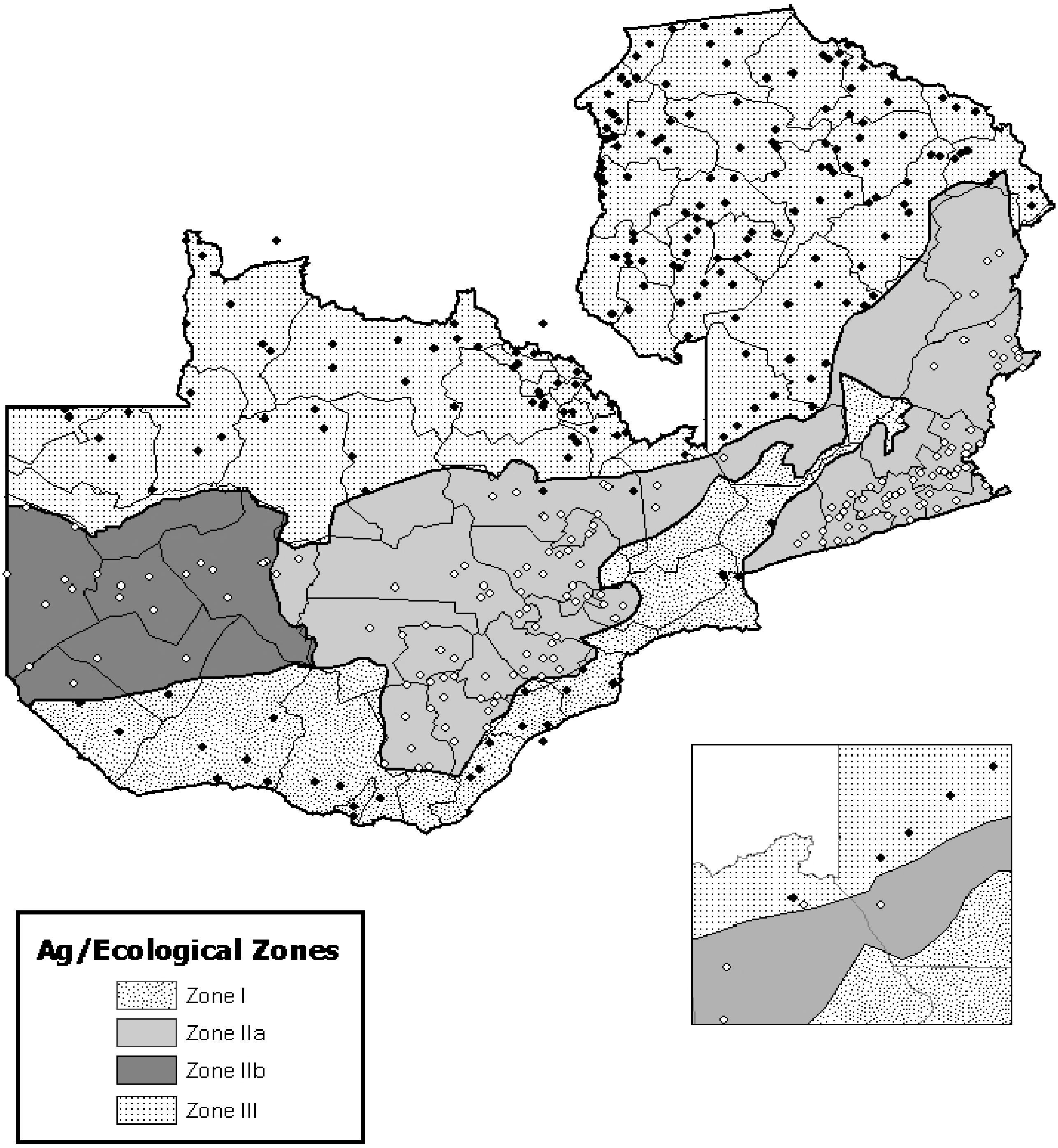
Annex F Map of Zambia

Map 1: Map of Central Statistical Office Statistical Enumeration Areas (SEAs) Sampled in the CSO/MACO/FSRP Post Harvest Survey in 1999/2000 and Supplemental Surveys in 2000/2001, 2003/2004 ar 2007/2008 by Zambia's Agro-Ecological Zones



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Map of Zambia Source: Central Statistical Office with support from the USAID-funded MSU Food Security Research Project. Pages 10-14 excerpted from: Kuteya, A., S. Kabwe, M. Beaver, A. Chapoto, B. Burke, N. Mason and M. Weber. 2011. Statistical Report on Categorization of Rural Cropping Households in Zambia: Section I –Introduction and Methods. FSRP Working Paper No. 51-1, Lusaka, Zambia. March draft. Full document available at:
http://aec.msu.edu/fs2/zambia/wp51/wp51_section_I.pdf