Smart Subsidies to Promote Peer Monitoring of Conservation Agriculture Compliance in Malawi

TITLE PAGE

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Abstract

Conservation agriculture (CA) in developing countries is a suggested technology which promotes food security and improved environmental amenities. Adoption of CA in many developing countries has been disappointing, arguably due to inadequately designed CA policies and insufficient economic incentives to overcome barriers to adoption. Evidence suggests adoption of CA increases with interventions that facilitate the transfer of experiential learning between farmers. In addition, institutions which create interdependence between farmers' economic decisions and capture the influence of social capital, lead to increased adoption and compliance with interventions to promote CA.

Herein we propose evaluating the impact of the agglomeration bonus incentive scheme (AP) on compliance to CA in Malawi's Shire Valley basin. In partnership with the Malawi Department of Land Resources and Conservation and the National Smallholder Farmers' Association of Malawi, and leveraging a recently funded evaluation of the AP led by the International Food Policy Research Institute, our research will evaluate the impacts of AP on the adoption of agricultural conservation technologies being promoted currently by the Government of Malawi, under different conditions of compliance monitoring, providing an understanding of the role that social pressures and interactions play in reducing monitoring costs and improving program effectiveness in this region.

Narrative Description

1 Rationale

Conservation agriculture (CA) in developing countries has received significant attention over the past several decades as a method of farming that promotes soil fertility and sustainable yields, reduces soil erosion, and sedimentation (Derpsch et al., 2010; Ficarelli et al., 2003). In Malawi, the application of CA, i.e. incorporating no-till, mulching and intercropping has been identified as a practice that should increase yield, particularly in low rainfall areas. However, adoption of CA practices in Malawi and other regions of Sub-Saharan Africa have been disappointing, arguably due to inadequately designed CA policies with insufficient economic incentives to overcome barriers to adoption for local farmers (Orr, 2003; Pannell et al., 2014). Some of the impediments to adoption have been identified as a lack of information about CA management practices, uncertainty concerning costs and benefits of CA practices, sensitivity to increases in yield variability, shorter planning horizons and high discount rates (Lee, 2005; Pannell et al., 2014).

Numerous global programs have been implemented over the past three decades in an effort to promote food security and quality of life through the increased adoption of CA in Sub-Saharan Africa (Derpsch et al., 2010; Giller et al., 2009). Although a few CA policies have been successful, generally barriers to adoption cause farmers to dis-adopt CA practices or to be in noncompliance with CA agreements before farmers can realize personal gains from CA techniques (Giller et al., 2009; Robbins et al., 2006). Incentive mechanisms that provide institutions for dispersing information regarding improved management practices are critical to the success of CA adoption (Lee, 2005). In this grant we propose the agglomeration bonus incentive scheme as such a mechanism (Parkhurst & Shogren, 2007, 2008; Parkhurst et al., 2002).

The agglomeration bonus is a two part incentive scheme: 1) a flat subsidy that induces landowners to voluntarily participate in the CA program; and 2) an agglomeration bonus paid to landowners when their land enrolled in the CA program shares a common border with a neighboring parcel also enrolled in the CA program. This interdependence between neighboring landowners' agriculture decision creates a positive network externality that provides an incentive for each adopting landowner to serve as an "extension agent" promoting CA to their neighbors, potentially increasing the rate of adoption in the community. Our current work suggests agglomeration bonus payments (AP) may also offset some program costs by reducing moral hazard and encouraging sustained adoption (Bell et al., in preparation). In this document we propose an evaluation of the reduction in moral hazard that AP may allow in the promotion of land conservation practices in Malawi's Shire Valley basin. A particular concern in this region has been land degradation and economic damages to downstream hydropower infrastructure associated with poor land-use practices upstream. In partnership with the Malawi Department of Land Resources and Conservation (DLRC) and the National Smallholder Farmers' Association of Malawi (NASFAM), and leveraging a recently funded evaluation of agglomeration payments led by the International Food Policy Research Institute (IFPRI), our research will evaluate the impacts of AP on the adoption of agricultural conservation technologies being promoted currently by the Government of Malawi, under different conditions of compliance monitoring, providing an understanding of the role that social pressures and interactions play in reducing monitoring costs and improving program effectiveness. This effort aligns closely with the theme of interventions to reduce barriers to adoption of improved agricultural technologies.

The IFPRI-led study, described in the following section, will compare a conventional encouragement (a flat subsidy in the form of a voucher) to an AP program, under perfect monitoring of compliance. Our proposed work will significantly expand the potential contribution of the IFPRI study by examining compliance in these two programs under different levels of monitoring.

As an example of the role monitoring plays in a developed country context, Giannakas and Kaplan (2005) construct a model and test the impact of monitoring and enforcement on noncompliance in a USDA subsidy program targeting highly erodible lands. In their analysis, a 1% increase in the probability of monitoring CA agreements caused a 0.12% decrease in noncompliance. In addition, the impact of increasing the expected penalty, through an increase in the size of the subsidy, caused a 0.33%

decrease in noncompliance for a 1% increase in the subsidy (Giannakas and Kaplan, 2005).[1] Segmenting farmers into groups of high risk noncompliance and low risk noncompliance, and employing a monitoring mechanism in which the rate of monitoring across groups maintains the mean penalty has theoretical promise for reducing noncompliance (Fraser, 2004).

In developing countries, individual adoption of and compliance to CA management plans may respond differently to conservation incentives and the expected penalty of noncompliance than the response of individuals in developed countries (Jones, 2008). Adoption of CA in developing countries is often hindered by the linkages between agricultural productivity on small farms and social and cultural values, as well as access to resources. Overcoming these obstacles to CA adoption requires the strengthening of organizations beginning at the village level, to promote dissemination of information and the transference of knowledge between farmers as they learn how to adapt CA techniques to the agricultural environment (Ficarelli et al., 2003). Further, social relationships have significant, complex effects on individual decisions within villages and communities in developing countries. Strong social relationships translate into social capital, which generates greater trust and reciprocity allowing individuals more access to economic resources and extended social networks within the individuals community. Ignorance of the impacts of social capital when implementing a CA management plan can have negative impacts on adoption and compliance (Hoang et al., 2006). In developing countries, crafting informal institutions that mesh with social norms within a community can be an effective approach to managing ecosystem services (Jones et al., 2008).

The agglomeration bonus has the potential to exploit inherent informal institutions of social norms, effectively regulating farmer's behavior within the farmer's village. Creating positive network externalities between neighboring farmers agricultural decisions could strengthen the village's organizational structure, promote information diffusion and transfer of technologies, and increase adoption and compliance of CA management. The impact of a detected noncompliance not only results

[1] To isolate the impact of changes in monitoring on noncompliance, we equate the expected value of the subsidy payments across incentive schemes.

in the loss of the CA subsidy for the farmer in noncompliance, but also imposes a cost on all neighboring landowners engaged in CA management who lose the AP associated with the shared border. If social norms increase the propensity for compliance to avoid social disapproval (Balliet et al., 2011; Grasmick & Green, 1980) and the loss of social capital, monitoring and enforcement costs will be smaller for an AP mechanism relative to a conventional encouragement mechanism.

2 Approach

Our two-pronged research strategy begins with a pilot study (4-treatment encouragement design) to evaluate the importance of monitoring effort across conventional voucher programs and AP programs aimed at improving adoption of conservation agricultural technologies under DLRC-led programs in the Shire Valley. The IFPRI-led evaluation with which this proposed research partners is a three-treatment pilot study (control, conventional voucher program, and agglomeration payment program) under perfect monitoring of compliance.

The treatments in this study will include a 2x2 design of monitoring effort (half-complete monitoring, no monitoring) over the conventional voucher and AP programs designed for the IFPRI study, leading to a 3x2, six-treatment design with control (Table 1).

Table 1: Linkage of proposed design and IFPRI-led, ESPA-funded design

	Full monitoring effort	**Partial monitoring effort**	**No monitoring effort**
Control	0 ESPA/BASIS		
SV	1 ESPA	3 BASIS	5 BASIS
SV + AP	2 ESPA	4 BASIS	6 BASIS

Second, we propose to contribute to the development of a coupled agent-based model (ABM) of the Shire Valley basin system to evaluate consequences of improved adoption of sustainable agricultural practices for the enhanced provision of ecosystem services such as improved water quality and runoff regulation, and/or increased natural predator and pollination services. For example, of particular concern to Malawi farmers are stem borers, whose negative impact on maize yields is known to be reduced under CA practices of intercropping (Kfir et al., 2002). Data on social interactions and decision making generated from our pilot study will inform this regional-scale ABM which, coupled to soil-water assessment models already developed for Sub-Saharan Africa and to literature models for provision of predator and pollination services, will allow assessment of the landscape-scale consequences of the different incentive schemes evaluated in the pilot study. The IFPRI-led study will also lead development of this modeling framework; our proposed work will augment the scope of this computational endeavor to include modules on monitoring and enforcement mechanisms, as informed by the proposed 4-treatment encouragement.

This two-pronged design overcomes a central challenge in evaluating impacts from projects focused on sustainable agricultural practices. That is, while some impacts (such as changes in labor and input costs) may accrue rapidly, others (such as shifts in yields or water quality) may take years of consistent CA implementation to emerge (FAO, 2012). The coupled pilot study and modeling exercise proposed here and in the IFPRI pilot study overcome this challenge by combining field data collection with agent-based and hydrologic simulations. The resulting analysis in conjunction with the conventional voucher and AP incentive schemes, captures many of the potential long-term environmental and ecosystem-service outcomes within a timeframe more amenable to research projects and decision-making processes.

The central research questions of the IFPRI-led ESPA study are:

Q1) *How do AP shift interactions among farmers, as well as rates/patterns of adoption of sustainable agricultural practices, such as CA?*

Q2) *Can AP lead to enhanced landscape-scale ecosystem service provision?*

Q3) *Do AP facilitate cost-effective ES provision, relative to conventional vouchers?*

Our proposed evaluation unpacks this third question, allowing disentanglement of the enhanced diffusion effects brought about by the AP-encouraged social interactions (measured in the IFPRI treatments 1 and 2) from the enhanced compliance (reduced moral hazard) effects emerging from the interdependencies of neighboring farmers agriculture decisions resulting from AP (measured by the proposed treatments 3-6). The third question is decomposed as:

Q3a) Do AP facilitate more cost-effective ES provision than conventional voucher programs, controlling for compliance levels?

Q3b) Do AP facilitate more cost-effective ES provision (and adoption) than conventional voucher programs, via a reduction in moral hazard or lower costs for monitoring effort?

Behavioral input for Q3a and Q3b is provided by the six treatments that combine the conventional voucher and the AP with varying monitoring levels in our two-pronged study; evaluation of cost effectiveness at the basin scale is facilitated by the integration of the two-pronged-study findings with our coupled ABM framework. Specifically, we test the following hypotheses:

H3.1) AP lead to higher levels of diffusion and overall adoption rates than conventional encouragements

H3.2) AP lead to higher compliance (and lower cheating rates) than conventional encouragements

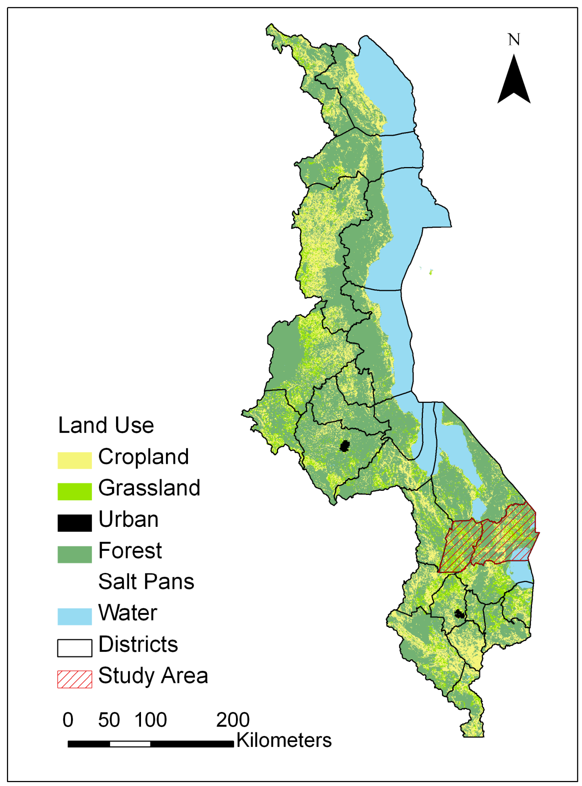
H3.3) Compliance in AP programs remains higher than conventional encouragements under reduced monitoring effort

H3.4) AP allow more cost-effective provision of ecosystem services than conventional encouragements

3 Pilot Study Design: Agglomeration payments in the Shire Valley

We will administer all three treatments in Balaka and Machinga Districts in Southern Malawi's Upper Valley Region (Map 1), covered by DLRC's "Environmental and Natural Resources Management Action Plan for the Upper Shire Basin" within its Agriculture Sector Wide Approach (ASWAp), promoting a range of conservation agriculture techniques such as soil cover, minimum tillage, and land-use diversification. (MCC Malawi, 2011).

The adoption of conservation practices in the Shire Valley remains low, and it is challenging to evaluate the impact of adoption through non-experimental approaches. Randomized control trials have a growing place in the context of agricultural programs (e.g., Duflo et al., 2007), but can be problematic in contexts where adoption places farmer income at risk. Additionally, results from such trials can be misleading at the landscape scale when the treatment includes large numbers of farmers who might not choose to participate in practice. We therefore propose a three-treatment encouragement design (Diamond & Hainmueller, 2007) – randomizing on the encouragement rather than the adoption – to evaluate household-level yield and profitability impacts and landscape-level impacts on water quality of sustainable agriculture technologies being promoted under a DLRC-led program to encourage CA technologies. Specifically, we will encourage the adoption of the set of 3 sustainable agriculture practices the DLRC is promoting under its CA initiative: i) minimum tillage, ii) crop residue retention, and iii) crop rotation or intercropping. Our design expands the control treatment of the IFPRI study, and adds four further treatments:



Map 1: Malawi and Study Area

i) Conventional Voucher program under partial monitoring (randomized monitoring of ½ of treatment households in each round) (CV 0.5)

ii) AP program under partial monitoring (randomized monitoring of ½ of treatment households in each round) (AP 0.5)

iii) Standard Voucher program under no monitoring (randomized monitoring of ½ of treatment households in each round) (CV 0)

iv) AP program under no monitoring (randomized monitoring of ½ of treatment households in each round) (AP 0)

AP have appeared recently in the experimental and ecological economics literature as a means of achieving spatial coordination in land use (Parkhurst & Shogren, 2007; Parkhurst et al., 2002), but to our knowledge this is the first application in a developing economy focused on agricultural management practices. In this study, payments will take the form of an input voucher (entitling the holder to a choice across a range of farm inputs such as fertilizers, but avoiding a direct cash payout), reflecting current policies for incentives in the Ministry of Agriculture, and which our previous experience and research in the area has shown a preference for (Marenya et al., in Review). Our previous work in the Shire Valley has suggested that encouragements equivalent to USD$20 are sufficient and fit local accepted practices for agricultural programs; however, our initial planning work with NASFAM and DLRC will include focus group discussions with local farmers, both to improve household survey design and to investigate sensitivity to smaller encouragements than currently planned. The use of vouchers will be advantageous by i) having more direct comparability to the proposed sustainable land management (SLM), and ii) providing opportunity to enhance existing engagements with private sector input providers in establishing the voucher system.

The proposed structure of the voucher program follows:

1) In treatments 1, 3, and 5 (Conventional Voucher) a voucher equivalent to USD$10 is available for CA adoption on ½ hectare of land, and a voucher equivalent to USD$20 is available for CA adoption on 1 hectare of land

2) In treatments 2, 4, and 6 (AP) a voucher equivalent to USD$5 is available for CA adoption on ½ hectare of land, and a voucher equivalent to USD$10 is available for CA adoption on 1 hectare of land. Additionally, for farmers that adopt CA over 1 hectare, an agglomeration

bonus of USD$2.5 is available for every neighboring plot abutting the recipients' CA plot that also adopts, to a maximum of four plots; for farmers that adopt at the ½ hectare level, the maximum number of neighboring plots for which a bonus is given is two. The maximum payment is thus equal to the payments in the Conventional Voucher treatments.

Vouchers are awarded only for new transitions to CA from traditional practices, with verification by a NASFAM/DLRC extension agent necessary for registering in the program. Registration in the program is capped at 100 participants in each replicate.

Over the short duration of this experiment, this four-treatment design is intended not to measure the effects CA can have on household-level profitability (which are currently intensively studied by other groups of researchers and known to require several seasons to accrue), but rather the effects that different incentive schemes (encouragements) can have on adoption rates and patterns, which in turn can have landscape-level impacts on water quality, and suspended sediment loads, in particular. The approach will also help us determine the effectiveness of farmers as information agents and neighborhood effects (Staal et al., 2002) for practices which have shown slow and/low adoption rates under the conventional extension services approaches.

3.1 Sampling Strategy

Our sampling design will be based on the engagement strategy for extension employed by DLRC and NASFAM, in which 'lead farmers' are engaged directly to promote particular technologies in their home villages. Typically, groups of around 5 lead farmers from the same village form a club, with groups of 5-10 clubs then forming a cluster with whom DLRC and NASFAM extension agents have direct and regular contact for the purposes of training and review. Replicates within our treatments will be at the village level, so that we will engage individual clubs to promote the program at the village level. Our treatment frame comprises the area within Machinga and Balaka districts under contact with DLRC and

NASFAM extension workers (representing 371 clubs); in consultation with field officers of DLRC and NASFAM, we will randomly select clubs within the districts such that:

- The cluster is separated from other selected clusters by a sufficient distance to minimize potential spillover and behavioral shifts in control groups (the "John Henry" effect).
- The clusters represent villages that are comparable in agricultural productivity, market access and rural population density to other clusters included in the study.

We will undertake 8 replicates (clubs) for each of our 6 treatments and 12 replicates for our control, for a total of 60 clubs engaged in the project. Within each of the villages represented by the 60 clubs across the treatments, we will randomly select 30 households for a baseline survey in June-July 2014. A midline assessment of compliance will be made by LUANAR jointly with NASFAM to monitor the programs (at the levels appropriate to the treatment) and administer vouchers, though a full midline survey will not be undertaken. An endline survey will be undertaken at the end of the agricultural calendar in June-July of 2016, allowing an interlude of two complete agricultural calendars to elapse. Endline surveys will be administered to all 30 households in each village.

The effort currently funded by ESPA for treatments 1 and 2 allow capture of a signal of farmers who over the first two agricultural calendars i) chose to adopt CA practices, ii) chose to adopt but abandoned intention early, iii) did not choose to adopt, and iv) are planning to adopt in the upcoming 2016 agricultural calendar. The proposed treatments 3-6 augment this set by capturing a signal of farmers who v) registered but did not adopt; and vi) registered, adopted but then dis-adopted, with the capacity to identify whether being monitored or not has an effect on these aspects of compliance. Though a lengthier pilot period would allow more thorough measurement of adoption and attrition across the sample, this abridged interval allows assessment of attrition during the most challenging initial stage of adoption, and provides sufficient time for knowledge regarding the program to spread among neighbors and provide a signal of enhanced adoption under AP incentives. Further, the infrastructure put in place by this study will allow us to pursue funding for a follow-up longitudinal assessment of the samples at a later time.

3.2 Design considerations

The baseline survey will not make mention of the encouragement, to minimize any possible survey effects. Though questions in the baseline survey enquiring about adoption of different techniques may pique interest in the same, our control treatment will provide a measure of the background survey effect this may have. The encouragement itself will not make mention of the conditions of other treatments, to minimize competitive behaviors among treatment groups (known as "Hawthorne" effects). There is some potential that farmers might alter their willingness to adopt technologies in anticipation of mid-line or end-line surveys, but we expect any such effects to be minimal given current low adoption rates and risk aversion among farmers to alter their farming practices. Behavioral changes of non-treatment and control groups ("John Henry" effects) and spillovers between treatments will be minimized by the geographic separation of the treatments (reducing the effects of "cross talk" between villages and households in different treatments), while spillovers within treatments will be observed by sampling households not receiving the encouragement in each survey. In the case of the Agglomeration Payment treatment, within-treatment spillover is expected by design. Baseline and endline surveys will be standardized surveys with both structured and open-ended questions regarding choices to adopt or not and how adoption shifted social interactions.

This design randomizes on the encouragement, which reduces the burden of identification. Our identification strategy for household-level effects will consist of regression with control for confounding factors (such as resource endowments, human capital and community factors).

Across all treatments there is a risk of attrition due to abandoning of the CA technology, or by refusal to participate in further surveys. We will use statistical methods to determine the attrition bias and – if necessary – use imputation or weighting methods (Kristman et al., 2005) to reduce it.

There is a chance for self-selection bias in our design, in the case that the choice to adopt is correlated with factors such as wealth or risk aversion. The Agglomeration Payment treatment partially addresses this by enhancing incentives to adopt once early-adopting neighbors have taken up the technology, encouraging a broader profile of risk-averse farmers to adopt than would occur otherwise.

Econometric procedures for correcting for self-selection and related simulations will enable us to demonstrate how the estimated impacts of CA vary with household characteristics – i.e., by showing how impacts change for larger (smaller) households, larger (smaller) farms, or male (female) headed households as compared to a median household. We note however the standard caveat that extrapolated values from models tend to be less reliable, so that the failure to capture particular demographics as adopters will limit the scope of these modeled econometric outputs.

3.3 Power calculation

While our study will collect data on household-level impacts of the intervention, our interest in designing the study is the detection of differences in adoption rates of the CA technology at the treatment scale, with replicates at the village scale (a clustered design with 8 clusters per treatment), and with background adoption rates in the control treatment are expected to be low. The simple random sample size for proportion inferences is given by:

$$N = K_{\alpha,\beta} \cdot \frac{p_1 \cdot (1 - p_1) + p_2 \cdot (1 - p_2)}{(p_1 - p_2)^2}$$

where $K_{\alpha,\beta}$ is a constant specific to the desired confidence (α) and power (β) of the sample. In this study, we have a single-stage cluster sample, in which similarities among members of clusters necessitate larger overall sample sizes than would be necessary under a simple random sample. Specifically, the effective sample size N_{eff} for a sample of K clusters with size m is:

$$N_{eff} = \frac{K \cdot m}{(1 + (m - 1) \cdot \rho)}$$

where ρ is the intra-cluster correlation coefficient, a measure of how much of the overall sample variability is explained by differences in the means of the clusters (i.e., how different the clusters are from each other) with respect to the measure of interest (here, adoption). Substituting N_{SRS} for N_{eff} and rearranging for the required size of each cluster we obtain:

$$m = \frac{1-\rho}{\frac{K}{N_{SRS}} - \rho}$$

Note that the denominator will be negative when the ratio K/N_{eff} is less than ρ, indicating that an equivalent sample size to the simple random sample cannot be obtained with K clusters. That is, high ρ necessitates a higher number of clusters to obtain an equivalent sample. There is no comparative data available on adoption at the village level; however, we note that it is very low overall in Malawi, and that we are designing for similarity in village-level characteristics across replicates, such that we have no basis to expect high ρ values across the sample. Though intervention is through particular lead farmers in each replicate, with their own incentives and interpretations of the program, we expect the regular contact with NASFAM and DLRC agents along the length of the study to help standardize understanding and presentation of the program, keeping ρ low.

Table 2: Confidence and power for different effect size and ρ, for 8 clusters of 30 HH per treatment

	$\rho = 0.05$	$\rho = 0.1$
From 0.1 to 0.3	β=0.05, α=0.05	β=0.1, α=0.05
From 0.1 to 0.2	β=0.5, α=0.05	N/A

Predicting *a priori* what the compliance rate will be in any of the treatments (i.e., how many farmers receiving the encouragement will adopt the CA technology) is a challenge. Again, our design benefits from levels that are currently very low across Malawi, since effects are more easily detected for low proportions. We are constrained by the nature of extension intervention, and by the need to keep replicates spaced, to engage via village-level clusters. Our selection of 30 HH in each of the 8 clusters per treatment has high power for moderate effect size, as long as the intra-cluster correlation is low with respect to adoption (Table 2); should effect size be particularly small, or ρ particularly high, our ability to make inference will be weaker.

4 Modeling Framework

As cited earlier, a challenge in evaluating CA is that while some impacts (such as reduced costs and labor requirements) accrue quite rapidly, others (such as shifts in yields or water quality) may take years of consistent practice to emerge (FAO, 2012). At the landscape scale, shifts in ecosystem service provision can be lagged and non-linear, exhibiting threshold changes that are difficult to capture within the scope of a pilot project. We overcome this limitation by combining field data collection with agent-based and hydrologic modeling simulations and the model-based approximation of other ecosystem services at the catchment scale using parameterization from the literature (Figure 1). These simulations allow us to project catchment-level impacts on multiple ecosystem services anticipated from the observed patterns of adoption and practice, as well as evaluate possible outcomes of targeted encouragements across the broader Shire Valley system.

Jointly with the IFPRI-led ESPA study, we will build an ABM of land-use decisions by

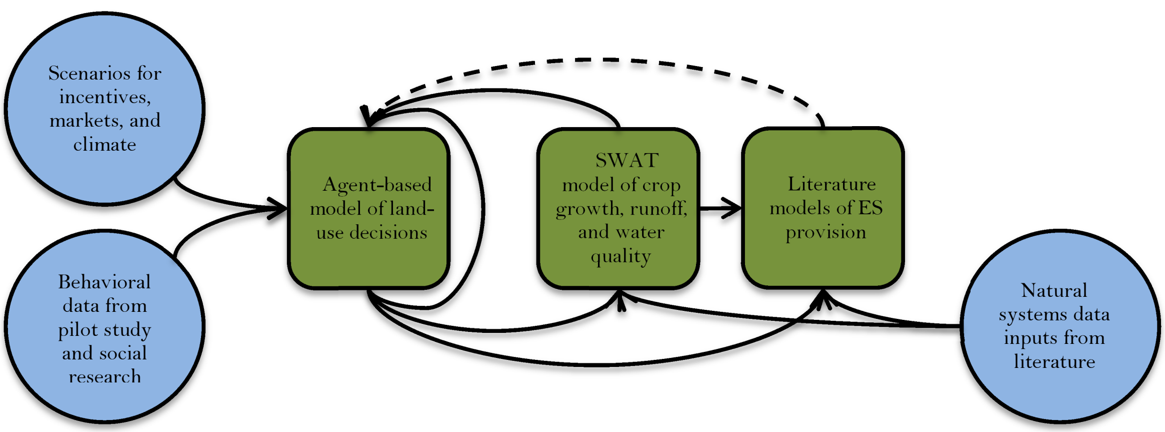


Figure 1: Linkages among field data, ABM, and other available models and frameworks for ecosystem service provision. Solid arrows denote necessary linkages of data and models; dashed arrows denote possible connections or 'loose' couplings.

smallholders – specifically, the adoption of CA practices – in response to a range of encouragements provided to the smallholders (such as extension services and payments). The ABM tracks the cost of such encouragements, and provides maps of agricultural development, income, and land-use across the modeled landscape. The land-use map can be coupled to a range of tools for estimation of environmental outcomes and ecosystem services provision. The first of these will be a hydrologic and crop-growth model of the Shire Basin built in the SWAT (Soil and Water Assessment Tool) platform (Di Luzio et al., 2004). Other coupled models will include frameworks such as the Polyscape framework (Jackson et al., 2013), which estimates the provision of a range of ecosystem services and the potential trade-offs in land-use decisions among provision of these services, as well as other available models for ecosystem service provision such as pollination (e.g., Lonsdorf et al., 2009). Coupling (see *3.4*) will be tight (on a per-time-step basis) to SWAT, and loose (serially, following the ABM simulation) for the estimation of ecosystem service provision.

4.1 Agent-based Model

Agent-based models treat actors in the system (such as farmers) as individual agents that follow a set of behavioral rules dictating their decisions in response to interactions with other agents and their environment (Brown, 2006). In ABMs, landscape-level outcomes such as land cover, water quality or ecosystem-level impacts emerge out of a set of agent-level decisions and interactions.

The basic model will include i) a hypothetical 2-dimensional landscape of land parcels, described by topography, soil, and land-use conditions appropriate to the study area, and ii) a set of agents each occupying one or more of the land parcels in the landscape. Initially, our model will be built on simple hypothetical conditions for topography and soils and simple crop models, as a means of isolating agent behavior for the purposes of model development and validation (see results from our current, stylized proof-of-concept model; Figure 2). Once developed, we will then apply spatial data layers for topography and soils specific to the region, derived for other SWAT modeling efforts within IFPRI, and couple the ABM with SWAT's capacity for modeling crop growth.

In each time-step in the ABM, agents update their knowledge base on environmental factors such as climate and crop responses, on market demands for crops via prices (set exogenously and varied across scenarios), on what kinds of policy incentives are being offered to them, and on what other farmers around them are choosing to do. Based on available information and a set of rules for making decisions, agents then make decisions about how to use their land (and implicitly, whether to participate in the program). The nature of these decision rules will be informed by our social research, but will likely take the form either of i) bounded rational optimizations on leisure time and income, with relevant social norms (such as ‘do as my neighbor does’) taking the form of constraints within the optimization, or ii) a decision tree structure of rules of thumb (such as ‘if prices for X are high, choose some amount of land to plant X’). The final set of rules will be chosen by validation against patterns of land use observed in our social research and decision-making reported by respondents.

4.2 SWAT Model

The algorithm of agent-environment interactions and land-use decisions in the ABM leads to a spatial pattern of land-use and of CA adoption (here, the practices of no-till and mulching as well as maintenance

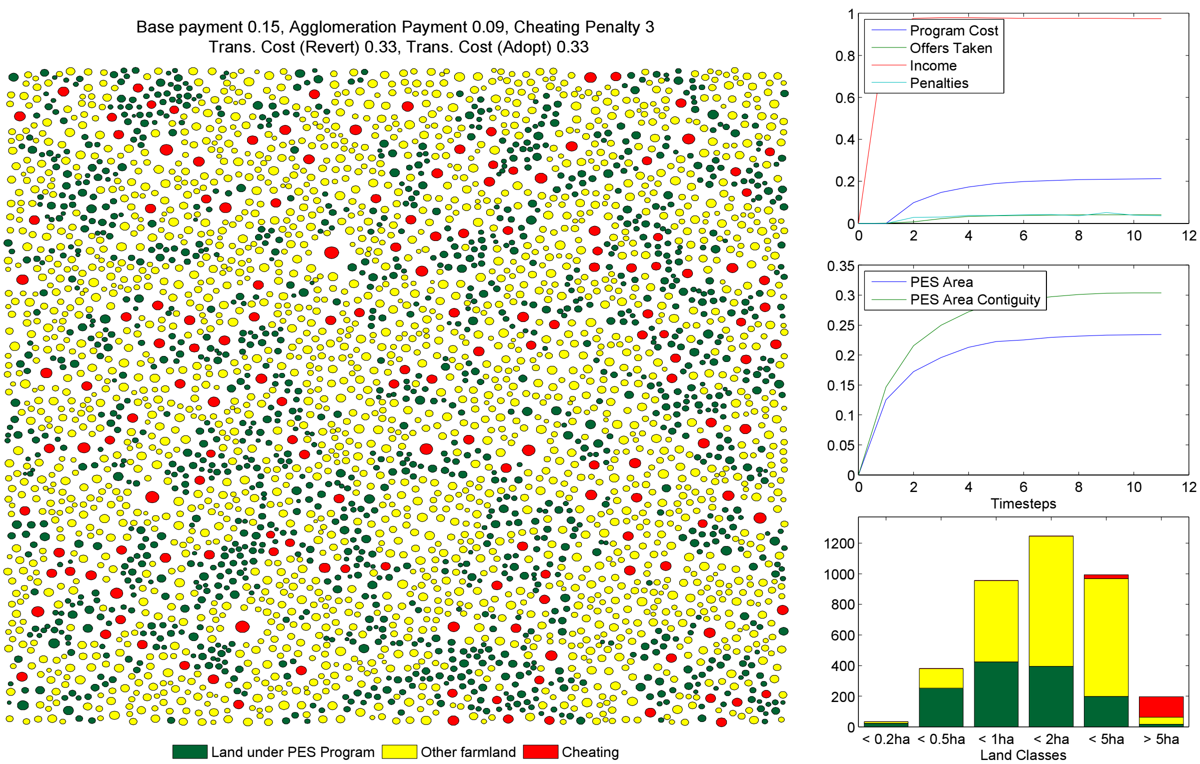


Figure 2: Proof-of-Concept model screenshot showing 2-D model space, program cost outcomes, landscape outcomes, and distribution of adopters. Each circle represents a smallholder plot, with farm size proportional to circle area. Model landscape is filled with farms to match a particular density of households and distribution of property sizes, leaving white space of ‘unmanaged land’ (also of interest in ecosystem service provision); farmer ‘neighbors’ are defined by a radius around each plot.

of non-crop vegetation) at the landscape scale. The SWAT platform is written in Visual Basic as an add-on to the ArcGIS software package, and is capable of simulating crop growth and hydrologic response to climate and land use, and will allow us to evaluate the broader impacts for activities such as the landscape level impacts on reduced river siltation due to adoption of CA technologies in different areas in the region. Via the SWAT model, we have the capability to i) model seasonal crop growth, for input back to the ABM, ii) model vegetative growth on non-managed land within the basin system, and iii) model hydrologic outcomes of water quality and runoff.

4.3 Other Ecosystem Service Models

The set of managed land-use maps from the ABM, as well as non-managed land-use and water maps from SWAT, can provide the basis of analysis for other land-based ecosystem service provision which is based on the amount, configuration, and type of land cover. Drawing from literature studies (e.g., Lonsdorf et al., 2009), we will parameterise land cover maps to estimate the impact of land use change on the principal ecosystem service of natural pest predators, using estimates of statistical kernels for service delivery around fragments of suitable habitat derived from meta-analysis of the literature (Shackelford et al., In Press) and expert knowledge of scientists working in East Africa. Overlaying these maps of water quality, runoff, pest predator habitat and the ABM maps of land use, it is then straightforward to examine the trade-offs and synergies between services (as, for example, has recently been done in the Polyscape project; Jackson et al., 2013).

4.4 Model Platform and Coupling

The ABM will be developed in the Matlab platform, allowing easy coupling to external model inputs and access to a wide range of statistical, mathematical, and visualization tools. Additionally, it allows the production of stand-alone executable files for non-programmer stakeholders to engage with.

Coupling across models will be accomplished via data management scripts in Matlab to convert outputs from one model process (such as the ABM) into appropriate model inputs (such as into spatial layers, either for input into SWAT, or into GIS for a Polyscape-like comparison of trade-offs). This process is less labor-intensive than developing truly coupled and integrated models, and allows flexibility in the level of coupling. Our social research efforts will reveal the extent to which farmer decisions are influenced by factors like crop responses or any shift in ecosystem responses – results produced by coupling to model frameworks like SWAT or Polyscape. In the event that these factors do not tie into decision making in any significant way, only a one-directional link is necessary (Figure 1). However, because inputs to the ABM from these other model frameworks can be achieved with simple scripts, we can also investigate the landscape-scale consequences of allowing signals from the environment to be more strongly integrated into the decision-making process.

5 Impacts and outreach

The IFPRI-led study began in December 2013 with two stakeholder workshops, in Lilongwe (to help tailor project outputs to current development objectives) and in the Shire Valley (to help tailor program design to local conditions). Engagement of agencies and NGOs locally engaged in the promotion of CA is expected throughout our pilot study efforts, with a second round of formal workshops planned for 2016. Our proposed study will engage a team of graduate students from LUANAR for enumeration and monitoring, with training in computer-assisted personal interviewing (CAPI) and the opportunity to use project data in thesis development. Additionally, we will engage two graduate students from the US across the project to assist in managing data collection and analysis and monitoring. As the development of our modeling framework progresses, we hope to integrate content on the use of models to support decision making into existing LUANAR curricula.

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Anticipated Outputs

This project leverages and enhances planned stakeholder outreach activities in the ESPA-funded project. An initial round of workshops was held in December 2013, engaging local lead farmers and extension officers in the Shire Basin to help tailor project design to local interests, and engaging policy and NGO stakeholders in the capital Lilongwe to identify key outlets for project outputs. Existing project funding exists for an end-of-project workshop in Lilongwe to disseminate outputs; we wish to augment these efforts to integrate a session (drawing on project findings) on cost-effective design of monitoring programs. Additionally, we intend a round of end-of-project visits to donors and agencies in Washington, DC with the same focus on cost-effective monitoring of programs, drawing on lessons learned in this project.

We plan in this effort to integrate our modeling efforts with those planned in the ESPA-funded project, as well as a recently completed effort by WorldFish that developed a decision-support tool for evaluating land-use influences on water. Our efforts will integrate an agent-based treatment of land-use decisions and response to monitoring programs into this tool, and we plan to train local stakeholders on the use of this tool as part of an add-on session to our planned end-of-project workshops.

We anticipate at least two publications stemming directly from our pilot study that evaluate the role of the agglomeration payment network externality in reducing the costs of monitoring in the program. We further expect our modeling efforts to facilitate a range of studies that examine the role that agglomeration payments can play at the landscape scale in cost-effective encouragement, as well as ecosystem service provision and water quality management.

Anticipated Impacts

The most direct goal of this planned research and the ESPA-funded project is to evaluate the cost effectiveness of agglomeration payments in improving adoption of conservation agriculture, enhancing the provision of ecosystem services, and managing sediment loading to the Shire River. Hydropower accounts for more than 90% of electricity generation in Malawi, and a very practical interest of this project is to evaluate whether agglomeration-payments-based adoption of conservation agriculture could be a cheaper alternative to dredging of sediment, and a better means of keeping electricity production robust. Thus, we expect to inform the potential for a viable payments-for-ecosystem services program, with hydropower production as a downstream beneficiary. The project aligns closely with the goals of a current World Bank project for catchment development in the Shire Basin, and we hope to work closely with colleagues at the Bank to ensure that insights from our research may inform Bank efforts, and vice versa.

More broadly, we expect our findings to have importance in illustrating the role that network externalities (such as created by the agglomeration payment) can have in improving the effectiveness of agricultural programs in smallholder landscapes where the costs of monitoring and enforcement can be prohibitive. Additionally, our Malawian partners will gain hands-on experience with innovative approaches such as agglomeration payments and monitoring of incentive-based programs, giving them a head-start in future roll-outs of these approaches.

Finally, we expect our efforts to have the very concrete and local impacts of training local graduate students in Malawi on the development and implementation of household surveys using computer-assisted personal interviewing (CAPI) technologies and on approaches to impact evaluation. We additionally plan to recruit two US graduate students to join in the survey and modeling work as a path to thesis development.

Timeline and Labor Distribution

Baseline data collection will begin prior to the beginning of the agricultural calendar in June 2014, with the pilot study efforts commencing upon completion of the baseline survey. Weber State will lead the survey and study design, with input from LUANAR. LUANAR will lead the baseline survey, with introduction of the program to lead farmers provided by DLRC and NASFAM, and additionally will undertake a midline compliance assessment (July 2015), and an endline survey in July 2016.

Model development will be led by IFPRI with input from Leeds, Weber State, and LUANAR, and will continue throughout the lifetime of the project, with insights into farmer decision processes revealed in our baseline survey, and an improved understanding of the role AP play in shaping network interactions revealed in the endline survey. Final analysis and reports will be completed by Sept. 30, 2017.

Summary of Qualifications

Dr. Parkhurst has pioneered the development of agglomeration payments in the experimental economics literature, as well as in the development of field and lab experiments. Drs. Benton and Bell share expertise in implementing surveys and framed field experiments in developing country contexts, as well as in the development of coupled modeling frameworks for natural-human systems. Dr. Mapemba has expertise in the implementation of field surveys and with interventions for promotion of conservation agriculture in particular.

Budget Justification

We request funds to implement a 4-treatment randomized encouragement study in parallel to an existing IFPRI-led 3-treatment trial. For Weber State University we request funding for one additional airfare to Malawi for PI Parkhurst and funds for domestic travel to conferences and meetings in the US. We ask for funding for 1.5 months of PI salary, 36 months of undergraduate student support, as well as 24 months of graduate student support and additional funds for contract labor. Finally we request support for one additional workshop (others funded by the IFPRI-led study) and for 3 publications.

We request for funds related to data collection to be allocated to LUANAR, including participant compensation for participation in the survey, payments for adoption of conservation agriculture, and costs associated with hiring and fueling vehicles for field transport. We also request funds for graduate student enumerators, and for 2 months of salary for PI Mapemba.

We request salary for IFPRI staff for survey design as well as model development, to purchase tablets for the survey, and a high-powered computer for simulation work. Finally, we request salary support for PI Benton to support model development.