DAAD
Deutscher Akademischer Austausch Dienst
German Academic Exchange Service

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Integrated Rainwater Harvesting Practices and Household Livelihood:

Evidence from a Counterfactual Analysis in Northeast Ethiopia

Anteneh Girma*, Menale Kassie**, Siegfried Bauer*, Joachim Aurbacher*

*Justus Liebig University Giessen, Germany
** International Maize and Wheat Improvement Center (CIMMYT), Nairobi, Kenya

September 08, 2014
JLU Giessen

Outline

- **Background and justification**
- **Estimation framework and estimation methods**
- **Data**
- **Results**
- **Conclusion and policy recommendations**

Agriculture in Ethiopia

- Half of the GDP and 80 % of employment (MoFED, 2012)
- In recent years, it has driven economic growth (World Bank, 2012)
- Smallholder and rain-fed
- Vulnerable to rainfall variability
  - **Food insecurity and poverty**
  - **Macroeconomics stability**

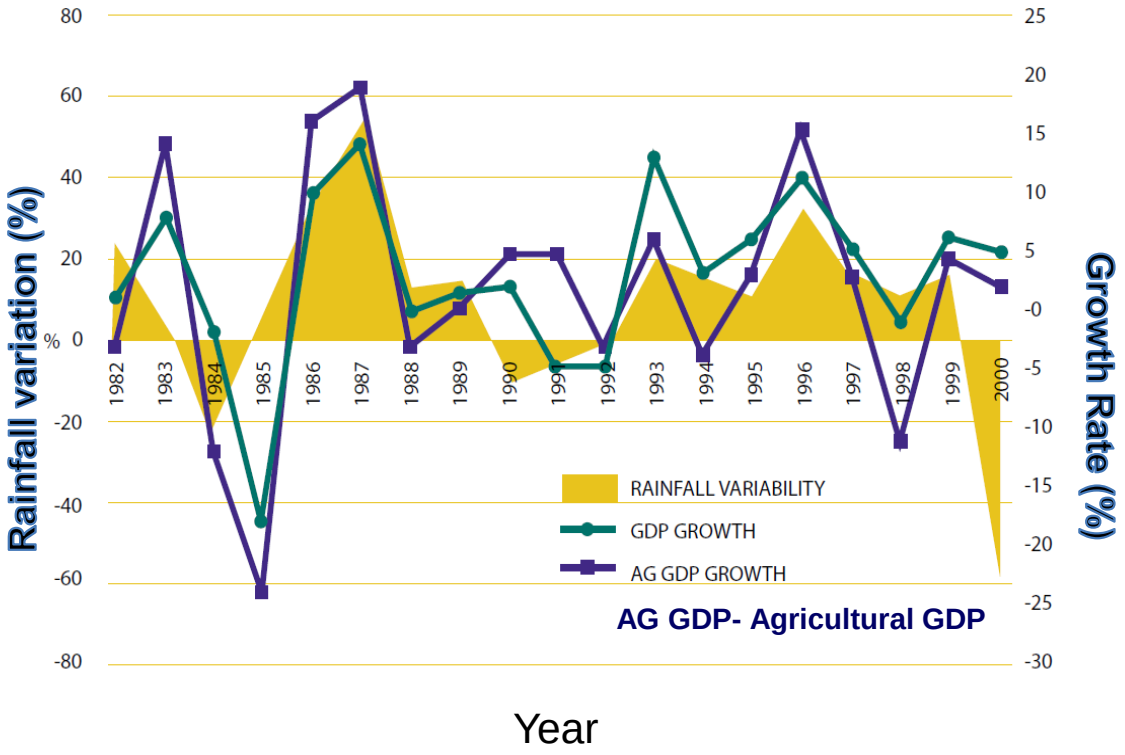

Figure 1: Ethiopian Economy and Rainfall
Source : De Jong , The world Bank (2005)

Drivers

- Natural – Rainfall intensity , topography , soil type
- Socio-political- population pressure , land use and cover

Problem

- Run-off erosion, nutrient depletion and land degradation
- Reduced productivity in land and water resources

High risk rainfed highland *** farming system (FAO, 2011).

Response

- Farmers' practices - manage the land and water resources
- Policy attention since 1973/74 (Shiferaw and Holden, 1999)

❑ **Integrated rainwater harvesting for sustainable intensification of smallholder rain-fed agriculture**

- Earlier studies
  - Examine adoption and performance of a single technology in multiple sites; Examine performance from a land, not water perspective **(MERREY and GEBRESILASIE, 2011).**
  - Focused on direct benefits (farm income, productivity, income based poverty) **(KASSIE et al; 2010, KATO et al, 2011; GEBREGZIABHER et al., 2012; HAGOS et al, 2012; FALCO & VERONESI, 2013; ABDULAI & HUFFMAN, 2014).**
  - Not modeled the interdependent and simultaneous adoption **(KASSIE et al., 2013**
- Understanding the factors and empirically measure the impacts of IRWHP
  - strategies for sustainable intensification of smallholder rainfed agriculture
- This research is initiated to address the true value of integrated rainwater harvesting practice – econometrics & integration option
- Investigate the factors that influence the decision to use integrated rainwater harvesting practices and their impact on sustainable rural livelihood in Ethiopia

Econometric framework and estimation strategy

- Sample selection bias
- Problem of counterfactual

Switch probit model (Loshin and Sajaia (2011)

❑ Two stage and three equations model

I. First stage: Regime determination rule : decision to use IRWHP and interpreted as treatment variable

II. Second stage
  - Two outcome function , condition on the selection equation
    - Regime 1 and regime 2
  - Probability of multidimensional food secure and /non-poor

First stage : Farmers decision to use IRWHP using probit model

Random utility formulation

Let U_0 – HH benefit from traditional practices (with out IRWHP)
U_{R-} HH benefit of using the IRWHP in one of the plots

- The i^{th} HH decided to use the IRWHP in one of the plots , if $R^*_i = U_R - U_0 > 0$

R^*_i is a latent variable determined by observed household, plot and location characteristics (X_i) and unobserved characteristics (μ_i)

$$R_i^* = z_i\gamma + \mu_i \qquad R_i = \begin{cases} 1 & \text{if } R_i^* > 0 \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

Second stage : Two regimes

$$\text{Regime 1: } Y_{1i}^* = \beta_1 X_{1i} + \varepsilon_{1i} \quad \text{, If } R_i = 1 \quad \text{..... (IRWHP users)} \qquad (2)$$

$$\text{Regime 2: } Y_{0i}^* = \beta_0 X_{0i} + \varepsilon_{0i} \quad \text{, If } R_i = 0 \quad \text{..... (Non-IRWHP users)} \qquad (3)$$

- The error terms are assumed to be jointly normally distributed with a mean-zero vectors and correlation matrix

$$\operatorname{cov}(\mu, \varepsilon_1, \varepsilon_0) = \begin{bmatrix} 1 & \rho_0 & \rho_1 \\ & 1 & \rho_{10} \\ & & 1 \end{bmatrix}$$

- ρ_s statistically significant: endogenous switching and sample selection bias.

- In addition to the nonlinearities of its functional form, the model also included one variable in Z which is not in X

- The model used full information maximum likelihood (FIML) methods

Expected effect of IRWHP on users , Treatment Effect on the treated (TT)

$$TT(x) = \Pr(Y_1 = 1 \mid \mathrm{R} = 1, \mathrm{X} = x) - \Pr(\mathrm{Y}_0 = 1 \mid \mathrm{R} = 1, \mathrm{X} = x)$$

$$\frac{\Phi_2(X_1\beta_1, Z\gamma, \rho_1) - \Phi_2(X_0\beta_0, Z\gamma, \rho_0)}{F(Z\gamma)}$$

Expected effect of IRWHP on non-users , Average Treatment Effect on the untreated (TU)

$$TU(x) = \Pr(Y_1 = 1 \mid \mathrm{R} = 0, \mathrm{X} = x) - \Pr(\mathrm{Y}_0 = 1 \mid \mathrm{R} = 0, \mathrm{X} = x)$$

$$\frac{\Phi_2(X_1\beta_1, -Z\gamma, -\rho_1) - \Phi_2(X_0\beta_0, -Z\gamma, -\rho_0)}{F(-Z\gamma)}$$

Expected effect of IRWHP on the population, Treatment Effect (TU)

$$TE(x) = \Pr(\mathrm{R} = 1, \mathrm{X} = x) - \Pr(\mathrm{R} = 1, \mathrm{X} = x) = \mathrm{F}(\mathrm{X}_1\beta_1) - F(X_0\beta_0)$$

where F is a cumulative function of the univariate normal distribution. Average treatment effect (ATT, ATU and ATE) are then derived after taking the mean of TT, TU and TE with the respective number of observations in the subgroups.

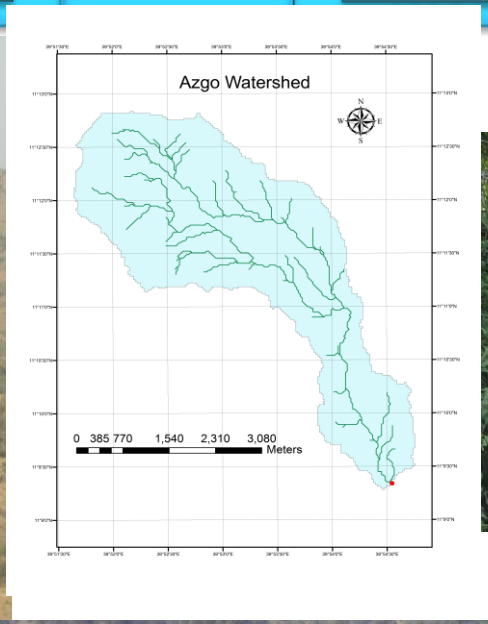

Figure 3. RWHP in the study watershed

Table 1. Rainwater Harvesting Practices (RWHP) in Azgo watershed

RWHPs	N	% of the practices	% of the Plot
No Structure	79	5.13	8.11
Soil Bund	250	16.23	25.67
Stone faced Soil Bund	281	18.25	28.85
Contour trench	42	2.73	4.31
Tie ridge	18	1.17	1.85
Stone Terrace/check dam	660	42.86	67.76
Planting Tree	14	0.91	1.44
Trench	18	1.17	1.85
Eye brow	12	0.78	1.23
Hillside terrace	24	1.56	2.46
Water harvesting Pond	93	6.04	9.55
Spring Diversion	44	2.86	4.52

Source: Own survey 2012

- ✓ Indigenous and introduced
- ✓ Enhance infiltration and/or reduce runoff
- ✓ Capture, store and use runoff and surface water emerging from farms and watershed
- ✓ There is a significant correlation between RWHPs: Use of RWHPs are interrelated

Table 2 . MFSI and MPI : Dimensions, indicators, cutoffs and weights (brackets)

Multidimensional index (MDI)	Dimension	Indicator	Cutoff for the probability of MDI
Household food security (MFS)	Availability (0.33)	Per capital food crop lands size (0.167)	Principal component analysis (pca) (1=Food secure, 0= food insecure) pca ≥ 0
		Per capita livestock size (0.167)	
	Utilization (0.33)	Per capita food calorie intake (0.33)	
	Access(0.33)	Per capita household income (0.085)	
		Share of cash crop land (0.085)	
		Household asset (0.085)	
		Distance to main road (0.085)	
Household poverty (MPI)	Education (0.33)	Years of Schooling (0.167)	Alkire and Foster methodology for MPI (1=Poor, 0=non-Poor) Deprivation > MPI =Poor, otherwise non-poor
		Literacy (0.167)	
	Health/ Nutrition (0.33)	Per capita food calorie intake (0.33)	
	Standard of Living(0.33)	Livestock assets (0.085)	
		House type (0.085)	
		Cooking fuel type (0.085)	
		Household assets (0.085)	

Source: Own construction

Table 3. Endogenous switching probit regression estimation for impact of IRWHP use decision on probability of multidimensional food security and poverty

Explanatory variables	Selection equation	Probability of multidimensional food secure		Probability of multidimensional poverty	
		Users of IRWH	Non-users	Users of IRWH	Non-users
Household head Age	-0.020*** (0.007)	0.033***(0.012)	0.030***(0.011)	-0.016* 0.009)	-0.004(0.010)
Household head Sex	0.433(0.309)	-1.925**(0.812)	-0.608*(0.367)	1.487***(0.539)	0.842**(0.341)
Family Labor	0.298***(0.087)	-0.469***(0.152)	-0.738***(0.166)	0.057(0.130)	0.099(0.126)
HH Non-farm income source	-0.788***(0.207)	0.188(0.481)	0.413(0.311)	-0.334(0.273)	-0.373(0.305)
Membership in farmer based org.	-0.096(0.241)	-0.326(0.381)	0.091(0.353)	0.152(0.292)	0.308 (0.311)
Total farm size	-0.239(0.223)	1.577(2.181)	-0.256(1.587)	0.002(1.149)	0.507 (1.558)
Livestock size	0.091(0.094)	0.053(0.157)	0.104(0.171)	-0.330**(0.142)	-0.283*(0.148)
Share of own cultivation	0.475(0.516)	-0.375(0.893)	-0.306(0.696)	0.826(0.762)	0.467(0.658)
Share of cash crop	0.753**(0.321)	0.432(1.942)	-0.868(1.462)	0.344(1.050)	0.239(1.513)
Top Landscape	-0.591***(0.173)	0.561**(0.262)	0.355(0.261)	-0.479**(0.200)	-0.286(0.226)
Low Landscape	-0.731**(0.320)	0.316(0.574)	0.361(0.392)	-0.837*(0.500)	-0.039(0.360)
Household farm-income[#]		0.000(0.000)	0.000**(0.000)	-0.000 (0.000)	-0.000(0.000)
Use of government extension service	0.538***(0.147)				
Share of plain slope plot of land	-0.434***(0.164)				
Share of sloppy plot of land	-0.162(0.268)				
Share of homestead plot	0.027(0.185)				
Constant	-0.832(0.762)	0.500(.645)	-2.519*(1.350)	-1.336(1.259)	1.405(1.252)
LR test of independent eqns. Chi2(1)		10.48***		7.61**	

Note: *, **, and *** denotes significance level at 10, 5, and 1%; robust standard errors in parentheses

[#] Predicted value

Source: Own result

- Different factors influence the use of the different practices and their integrated use
  - Resource system
    - Crop type, position in the landscape & land characteristics
  - Household related factors - Labor supply
  - Role of government support services
  - Financial viability

Table 4. Treatment effects of IRWHP use on multidimensional food security and poverty status

Farm-household type	Probability of multidimensional food secure			Probability of multidimensional poor		
	ATT	ATU	ATE	ATT	ATU	ATE
Location						
Upper landscape	0.632	0.519	0.563	-0.466	-0.595	-0.571
Middle landscape	0.540	0.477	0.524	-0.373	-0.564	-0.484
Lower landscape	0.504	0.563	0.508	-0.743	-0.793	-0.749
Age category						
18-35	0.531	0.567	0.542	-0.370	-0.636	-0.482
35-50	0.578	0.531	0.532	-0.468	-0.654	-0.587
50-65	0.659	0.504	0.562	-0.468	-0.620	-0.608
65-80	0.488	0.494	0.536	-0.442	-0.621	-0.608
Sex						
Male	0.581	0.521	0.538	-0.434	-0.643	-0.569
Female	0.827	0.525	0.584	-0.722	-0.606	-0.659
Livestock size (TLU)						
No livestock holding	0.582	0.611	0.604	--	-0.794	-0.774
Less than 1 TLU	0.577	0.431	0.501	-0.458	-0.671	-0.602
Own 1 to 2 TLU	0.622	0.410	0.446	-0.435	-0.576	-0.557
Own 2 to 3 TLU	0.600	0.360	0.389	-0.524	-0.613	-0.536
Own more than 3 TLU	0.736	-	0.485	-0.341	-0.354	-0.389
Total	**0.590*** (0..002)**	**0.522*** (0.001)**	**0.544*** (0.000)**	**-0.44*** (0.001)**	**-0.64*** (0.000)**	**-0.58*** (.000)**

Note: Average treatment effect on the treated (ATT); Average treatment effect on the treated (ATU); Average treatment effect (ATE)

*, ', and " denotes significance level at 10, 5, and 1%; Bootstrapped standard errors in parentheses & calculated by bootstrapping with 200 replication

Source: Own result

- IRWHP have significant positive impacts to improve household livelihood:
  - increased the probability of multidimensional food security and
  - reduced the probability of multidimensional poor.
- IRWHP is more important for non users, would have benefited more
- Heterogeneity - some characteristics (eg: unobserved skills) made the users better off
- Selection bias – negative selection – farm households with lower food security status and higher probability of poverty are more likely to integrate RWHP.
- The gain in household multidimensional food security and poverty reduction diminishes as the farm household's propensity to use IRWHP increases

Recommendations

- Strategies to make use of rainfall as a source of agricultural water management option as a continuum from rain-fed to irrigated agriculture

- Enhance participation of poor farmers in the promotion of IRWHPs
  - – Government extension service
  - – NGOs and projects

- Enhance private sector participation in the supply of RWH inputs
  - – Private sector development in service delivery
    - Government strategies
    - Other initiatives

I thank you all