

# Climate change perception and system of rice intensification (SRI) in Tanzania

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# Introduction

- Climate change predicted to disproportionately affect Africa through substantial agricultural yield losses
- Adaptation strategies such as adoption of technologies that raise farmers' crop productivity while improving yield stability are particularly valuable.
- We assess impact of an unconventional adaptation strategy, the System of Rice Intensification (SRI) in Tanzania on mean yield and household income, and on their variability and exposure to downside risk
- We also analyse the role of farmers' perception of climate change in this context

# System of rice intensification (SRI)

- SRI was developed in the 1980s in Madagascar to help poor farmers increase yields, while reducing water use and using cheap organic inputs.
- SRI relies on moist soil, with intermittent irrigations and not on flooding. It is based on four principles
  - early transplanting (8 to 15 days old) of carefully managed seedlings;
  - widely spaced transplants to allow early and regular mechanized weeding;
  - careful and controlled water management; and
  - application of compost to the extent possible
- In many studies, SRI has delivered substantially higher yields, while reducing input requirements (fewer seeds, less water and inorganic fertilizers) than the conventional paddy method
- SRI is reported to produce more robust and resilient crops in the face of extreme weather events, pests, and disease

# System of rice intensification (SRI)

- These outstanding outcomes should help poor and vulnerable farmers increase yields and incomes
- However, slow adoption rate and high rate of disadoption among poor farmers
- Moser and Barrett (2003, 2006) attribute the puzzling finding to the large hidden opportunity costs of engaging in SRI.
- Labour intensity of SRI: reallocation of paid off-farm labour into unpaid family farm labour
- SRI is new and unfamiliar to farmers, so need for sustained training and extension services.
- When these services are unavailable, farmers may have little incentive to adopt SRI.

# System of rice intensification (SRI)

- Yet another explanation: SRI may have impacts beyond the mere average yields and average income.
- If SRI were to have an impact on the variability and risk of lower yields and income, then these impacts could also help explain this puzzle.
- In this paper, we explore this third and complementary avenue to understand the puzzlingly low adoption of SRI
- Our empirical strategy relies on an endogenous switching regression model that estimates jointly:
  - the selection into SRI, and
  - the effect of SRI on expected rice yield and Hh income, but also on their variance and skewness.
- Our analysis also highlights the importance of farmers' climate perception, both on the adoption decision and on the moments of yield and income.

# Econometric methodology: endogenous switching regression model (ESR)

- The ESR model consists of two stages.
  - The first stage is a selection equation: that is based on a dichotomous choice function (probability of adopting SRI).

$$SRI_i^* = S_i' \gamma + v_i$$
$$SRI_i = \begin{cases} 0 & \text{if } SRI_i^* \leq 0 \\ 1 & \text{if } SRI_i^* > 0 \end{cases}$$

- The second stage is the outcome equations (yield or income) for both non-adopters and adopters.

$$\text{Regime 0: } y_{0i} = X_i' \beta_0 + \varepsilon_{0i} \text{ if } SRI_i = 0$$

$$\text{Regime 1: } y_{1i} = X_i' \beta_1 + \varepsilon_{1i} \text{ if } SRI_i = 1$$

- ESR finally enables us to estimate the average treatment effect on both the treated (ATT) and the untreated households (ATU).

|                              | (1)        | (2)               | (3)                | (4)                |
|------------------------------|------------|-------------------|--------------------|--------------------|
|                              | Income OLS | Mean Income       | Variance of Income | Skewness of Income |
| <b>Panel C: SRI Equation</b> |            |                   |                    |                    |
| Household size               |            | 0.110* (0.063)    | 0.109* (0.063)     | 0.109* (0.065)     |
| Married                      |            | 0.560 (0.394)     | 0.577 (0.396)      | 0.580 (0.405)      |
| Male                         |            | -1.288*** (0.448) | -1.276*** (0.446)  | -1.280*** (0.447)  |
| Education                    |            | 0.111* (0.059)    | 0.111* (0.058)     | 0.112* (0.058)     |
| Experience with rice         |            | 0.023* (0.012)    | 0.023* (0.012)     | 0.023* (0.013)     |
| Log wealth                   |            | 0.252** (0.104)   | 0.248** (0.105)    | 0.249** (0.106)    |
| Total labor                  |            | 0.001 (0.001)     | 0.001 (0.001)      | 0.001 (0.001)      |
| Plot size                    |            | -1.088*** (0.290) | -1.080*** (0.288)  | -1.083*** (0.289)  |
| Very fertile soil            |            | 1.204*** (0.307)  | 1.189*** (0.301)   | 1.194*** (0.303)   |
| Slopy plot                   |            | -0.191 (0.269)    | -0.187 (0.267)     | -0.188 (0.268)     |
| Plot distance                |            | -0.053** (0.023)  | -0.051** (0.023)   | -0.051** (0.024)   |
| Distance to market           |            | 0.001* (0.001)    | 0.001* (0.001)     | 0.001* (0.001)     |
| Agriculture                  |            | 0.562 (0.673)     | 0.602 (0.652)      | 0.613 (0.654)      |
| Extension                    |            | 1.083*** (0.235)  | 1.064*** (0.233)   | 1.072*** (0.235)   |
| Rainfall decrease            |            | 0.557** (0.229)   | 0.552** (0.227)    | 0.553** (0.229)    |
| Temperature increase         |            | -0.467* (0.249)   | -0.462* (0.250)    | -0.461* (0.250)    |
| Social connections           |            | 1.222*** (0.373)  | 1.194*** (0.370)   | 1.194*** (0.378)   |
| Seed sorting                 |            | 1.498*** (0.253)  | 1.515*** (0.248)   | 1.514*** (0.250)   |
| Constant                     |            | -6.357*** (1.676) | -6.350*** (1.656)  | -6.377*** (1.658)  |
| $\sigma_1^2$                 |            | 1.919*** (0.197)  | 22.989*** (0.344)  | 0.358 (0.383)      |
| $\rho_{1v}$                  |            | -0.162* (0.096)   | -0.074 (0.067)     | -0.103 (0.207)     |
| $\sigma_0^2$                 |            | 1.487*** (0.184)  | 10.483*** (0.256)  | 0.094 (0.291)      |
| $\rho_{0v}$                  |            | -0.077 (0.293)    | -0.047 (0.205)     | -0.041 (0.691)     |
| Chi Test Indep               |            | 2.821*            | 1.225              | 0.249              |
| P-Value Chi test Indep       |            | 0.093             | 0.268              | 0.617              |
| <b>Admissibility Tests</b>   |            |                   |                    |                    |
| Chi Test SRI eq.             |            | 43.66***          | 50.79***           | 50.66***           |
| P-Value Chi test             |            | 0.000             | 0.000              | 0.000              |
| Chi Test Outcome eq.         |            | 0.21              | 2.32               | 4.00               |
| P-Value Chi test             |            | 0.646             | 0.313              | 0.135              |
| Number of Countries          | 332        | 332               | 332                | 332                |
| Log Pseudo-Likelihood        | -672.115   | -735.022          | -1486.371          | -27.541            |

Robust standard errors in parentheses \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

**Table 3:** Determinants of Income and SRI: Endogenous Switching Regression Model

|  | OLS         |         | Endogenous Switching Regression |         |                    |          |                    |         |
|--|-------------|---------|---------------------------------|---------|--------------------|----------|--------------------|---------|
|  | (1)         |         | (2)                             |         | (3)                |          | (4)                |         |
|  | Mean Income |         | Mean Income                     |         | Variance of Income |          | Skewness of Income |         |
| <b>Panel A: Income if <math>SRI = 1</math></b> |             |         |                                 |         |                    |          |                    |         |
| Household size                                 | 0.028       | (0.049) | 0.057                           | (0.060) | -0.406             | (0.564)  | -0.009             | (0.012) |
| Married  | 0.493*      | (0.273) | 0.898**                         | (0.407) | 6.151              | (4.228)  | 0.079              | (0.057) |
| Male   | -0.018      | (0.250) | -0.423                          | (0.341) | -0.698             | (2.753)  | -0.007             | (0.051) |
| Education                                      | 0.043       | (0.035) | -0.035                          | (0.048) | -0.306             | (0.364)  | -0.002             | (0.007) |
| Experience with rice                           | -0.011      | (0.013) | -0.021                          | (0.014) | -0.279**           | (0.137)  | -0.003             | (0.002) |
| Log wealth                                     | 0.106       | (0.086) | 0.120                           | (0.111) | -0.104             | (1.175)  | -0.003             | (0.022) |
| Total labor                                    | 0.008**     | (0.004) | 0.007**                         | (0.003) | 0.137***           | (0.044)  | 0.002***           | (0.001) |
| Plot size                                      | -0.024      | (0.028) | 0.024                           | (0.216) | 3.845*             | (2.044)  | 0.060              | (0.058) |
| Fertile soil                                   | 0.424**     | (0.200) | 0.566*                          | (0.307) | 3.030              | (2.467)  | 0.036              | (0.036) |
| Slopy plot                                     | -0.204      | (0.280) | -0.258                          | (0.253) | -3.090             | (2.086)  | -0.041             | (0.029) |
| Plot distance                                  | 0.038       | (0.025) | 0.052                           | (0.032) | 1.127***           | (0.410)  | 0.017***           | (0.006) |
| Distance to market                             | 0.000       | (0.000) | 0.000                           | (0.000) | -0.001             | (0.003)  | -0.000             | (0.000) |
| Agriculture                                    | -0.883      | (0.625) | -3.302***                       | (1.256) | -25.215**          | (11.617) | -0.331**           | (0.168) |
| Extension                                      | 0.165       | (0.210) | 0.255                           | (0.247) | 0.116              | (2.892)  | -0.005             | (0.025) |
| Rainfall decrease                              | -0.002      | (0.174) | -0.177                          | (0.257) | -0.081             | (2.552)  | 0.001              | (0.025) |
| Temperature increase                           | 0.558***    | (0.163) | 0.693***                        | (0.214) | 5.221***           | (1.927)  | 0.066*             | (0.038) |
| Constant                                       | -1.169      | (1.269) | 1.483                           | (1.893) | 12.586             | (16.256) | 0.142              | (0.384) |
| <b>Panel B: Income if <math>SRI = 0</math></b> |             |         |                                 |         |                    |          |                    |         |
| Household size                                 |             |         | -0.085                          | (0.089) | -0.700             | (0.718)  | -0.007             | (0.005) |
| Married  |             |         | 0.075                           | (0.339) | 1.764              | (1.704)  | 0.018              | (0.024) |
| Male   |             |         | 0.489                           | (0.309) | 2.220              | (1.706)  | 0.018              | (0.019) |
| Education                                      |             |         | 0.030                           | (0.033) | -0.075             | (0.183)  | -0.001             | (0.003) |
| Experience with rice                           |             |         | 0.033                           | (0.028) | 0.270              | (0.232)  | 0.002              | (0.002) |
| Log wealth                                     |             |         | 0.065                           | (0.111) | -0.795             | (0.688)  | -0.007             | (0.013) |
| Total labor                                    |             |         | -0.007*                         | (0.004) | -0.037*            | (0.021)  | -0.000             | (0.000) |
| Plot size                                      |             |         | -0.052                          | (0.032) | -0.135             | (0.183)  | -0.001             | (0.004) |
| Fertile soil                                   |             |         | 0.363                           | (0.243) | 2.164              | (1.641)  | 0.020*             | (0.011) |
| Slopy plot                                     |             |         | 0.137                           | (0.519) | 2.689              | (4.214)  | 0.026              | (0.041) |
| Plot distance                                  |             |         | 0.020                           | (0.029) | 0.168              | (0.179)  | 0.002              | (0.002) |
| Distance to market                             |             |         | -0.000                          | (0.001) | -0.002             | (0.004)  | -0.000             | (0.000) |
| Agriculture                                    |             |         | 0.720**                         | (0.359) | 4.709              | (2.879)  | 0.042*             | (0.023) |
| Extension                                      |             |         | -0.302                          | (0.302) | -2.786*            | (1.426)  | -0.023             | (0.045) |
| Rainfall decrease                              |             |         | 0.199                           | (0.261) | 2.600              | (1.832)  | 0.023              | (0.018) |
| Temperature increase                           |             |         | 0.347                           | (0.211) | 0.790              | (1.281)  | 0.011              | (0.012) |
| Constant                                       |             |         | -1.526                          | (1.180) | 1.375              | (6.477)  | 0.003              | (0.104) |

Robust standard errors in parentheses \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$



**Table 4:** Average treatment effect on adopters and non-adopters

|   |            | Rice Yield      |                | Total Income    |                |
|---|------------|-----------------|----------------|-----------------|----------------|
|   |            | (1)             | (2)            | (3)             | (4)            |
| <b>Panel A: Treatment effects on the adopters (ATT)</b>     |            |                 |                |                 |                |
| Moment  | Variable   | Mean            | Std. Err.      | Mean            | Std. Err.      |
| Type  |            |                 |                |                 |                |
| Mean  | Adopt      | 7.507           | (0.413)        | 1.577           | (1.166)        |
|   | Not adopt  | 6.655           | (0.310)        | 0.862           | (0.837)        |
|   | <b>ATT</b> | <b>0.852***</b> | <b>(0.040)</b> | <b>0.715***</b> | <b>(0.130)</b> |
| Variance  | Adopt      | 0.860           | (0.957)        | 5.047           | (15.468)       |
|   | Not adopt  | 0.919           | (0.410)        | -0.056          | (5.586)        |
|   | <b>ATT</b> | <b>-0.059</b>   | <b>(0.076)</b> | <b>5.103***</b> | <b>(1.393)</b> |
| Skewness  | Adopt      | 0.111           | (3.173)        | 0.054           | (0.243)        |
|   | Not adopt  | -2.000          | (0.936)        | -0.006          | (0.048)        |
|   | <b>ATT</b> | <b>2.111***</b> | <b>(0.244)</b> | <b>0.060***</b> | <b>(0.020)</b> |
| Observations  |            | 188             |                | 193             |                |
| <b>Panel B: Treatment effects on the non-adopters (ATU)</b> |            |                 |                |                 |                |
| Moment  | Variable   | Mean            | Std. Err.      | Mean            | Std. Err.      |
| Type  |            |                 |                |                 |                |
| Mean  | Adopt      | 7.241           | (0.641)        | 1.491           | (1.031)        |
|   | Not adopt  | 6.847           | (0.242)        | 1.130           | (0.508)        |
|   | <b>ATU</b> | <b>0.394***</b> | <b>0.053</b>   | <b>0.361***</b> | <b>(0.099)</b> |
| Variance  | Adopt      | 1.384           | (0.939)        | 11.006          | (13.812)       |
|   | Not adopt  | 0.471           | (0.355)        | 2.529           | (3.477)        |
|   | <b>ATU</b> | <b>0.913***</b> | <b>(0.085)</b> | <b>8.477***</b> | <b>1.264</b>   |
| Skewness  | Adopt      | 5.708           | (3.834)        | 0.150           | (0.206)        |
|   | Not adopt  | -0.516          | (0.805)        | 0.015           | (0.031)        |
|   | <b>ATU</b> | <b>6.224***</b> | <b>(0.354)</b> | <b>0.136***</b> | <b>(0.018)</b> |
| Observations  |            | 137             |                | 139             |                |

Bootstrapped standard errors in parentheses \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Number of replications: 10 000.

# Conclusion

- Impact evaluation analysis of the recent introduction of SRI in Tanzania, with a focus on risk for rice yield and household income
- Despite the recentness of the intervention (2006), we find evidence of large economic impacts of SRI adoption.
- Overall, SRI adoption comes with a trade-off between greater expected income and increased income variability.
- No such trade-off exists for rice yields: this increased risk in income could be due to reallocation of labour
- We also find that SRI has a considerable impact on reducing downside risk, which suggests that the reluctance of risk averse farmers may be mitigated by reduced downside risk.
- We provide evidence of the importance of climate change perception in shaping the decision to adopt SRI.
- In particular, perception of rising temperatures are associated with increased yields and income as well as their variance and skewness.