# The Role of Land Market in Achieving the Scale for Adaptation to Climate Change: Evidence from Bangladesh

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November 8, 2023

# Can Farmers Adapt by Reallocating Farmlands?

- Climate change induced shocks are affecting agricultural productivity: e.g., extreme temperature, drought, salinity intrusion
- Farmers in developing countries are heavily exposed to these shocks
- Ricardian view: effects can be mitigated if farmers reallocate lands according to evolving comparative advantage (Costinot et al., 2016)
  - Drought: cotton to beans, rice to fruit
  - Salinity intrusion: rice to aquaculture
- In practice, rate of reallocation might be slow in developing countries: frictions

# Frictions in Reallocation Process

- High fragmentation of farmlands in developing countries Farm Size
- Switching to farming with higher economies of scale needs consolidation
  - Example: rice to fruit, rice to aquaculture
- Potential barriers to farm size consolidation:
  - Sales: cultural barrier in selling lands inherited across generations
  - Rental: weak de-facto property rights, poor contract enforcement
- High fragmentation $\rightarrow$ multiple transactions for consolidation $\rightarrow$ hold up problems

# Research Questions

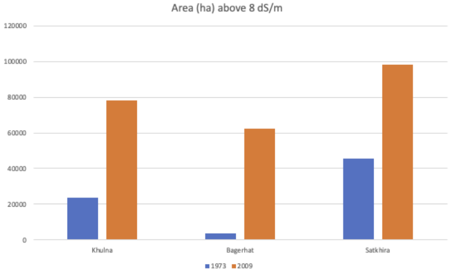
- To what extent farmers can switch to farming techniques with higher scales in response to climate shocks?
- What mechanisms enable smallholders to achieve the scale required for reallocation? Does land market play any role in it?
- What frictions limit the extent of land reallocation?

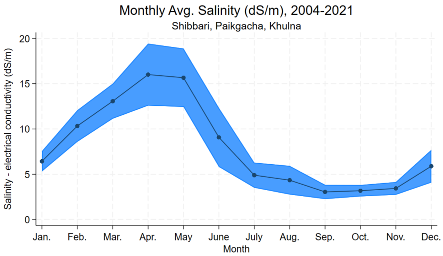
# Overview of This Paper

- Context:
  - Salinity intrusion in coastal farmlands of Bangladesh
  - Adaptation by reallocating farmlands from crop farming to aquaculture
  - Minimum scale in aquaculture: needs consolidation for adaptation
- Findings:
  - Salinity $> 12$ dS/m: land allocated to aquaculture doubles, 17% increase in farm size concentration
  - No evidence of ownership consolidation, farm size consolidation through rental market of land
  - Evidence on friction: lower religious diversity decreases land reallocation by half
  - Back of the envelope estimation: annual loss of approx. $450 in farm income per household

# Salinity Intrusion in Bangladesh

- Massive increase in dry season soil salinity




- Impact on resilient varieties of rice:
- BRRI Rice-47: No impact on productivity upto 8 dS/m, declines by 43% at 12 dS/m (Radanielson et al., 2018)
- New resilient varieties: BRRI Rice-99 and BINA Rice-10 are resilient up to 12 dS/m

# Adaptation to Salinity Intrusion

- Strategy: reallocating farmlands to aquaculture in dry season, prevalent in China, India, Indonesia, Vietnam
- Primarily shrimp and crab farming, ideal salinity level 10-20 dS/m

- Aquaculture has a minimum scale of about 35 decimals Scale
- Median agricultural plot size is 18 decimals → reallocation requires consolidation

# Salinity: Survey Data

- Soil salinity data from Soil Resources Development Institute (SRDI) survey 2009
  - 2500 sample points
  - Divides coastal region into five categories: 0 to 4 dS/m, 4.1 to 8 dS/m, 8.1 to 12 dS/m, 12.1 to 16 dS/m, above 16 dS/m
  - 40 percent of the villages have more than 12 dS/m salinity
- Agricultural Census 2008:
  - Full count, household level survey
  - Land use, land ownership, land rented in, land leased out

# Key Model Assumptions

- Two crops: productivity of crop 1 (agriculture) declines with salinity, and crop 2 (aquaculture) thrives in salinity
- Each farm is endowed with $\bar{l}_{iv}$ farmland and crop specific TFP given by $z_{1,i}$ and $z_{2,i}$
- $y_{1,iv} = \frac{z_{1,i}}{S_v} * l_{1,iv}^{\gamma_1}$, $y_{2,iv} = z_{2,iv} S_v * l_{2,iv}^{\gamma_2}$, where $\gamma_2 > \gamma_1$
- Farmers can't sell their endowed lands so that land transactions occur only through rentals
- Farm specific transaction costs:
  - $\tau_{1,iv} = \tau_{iv}$ = transaction costs in the rental market
  - $\tau_{2,iv} = \tau_{iv} + \psi_{iv}$, where $\psi_{iv}$ denotes additional costs for consolidation
- Farmers choose amount of land to rent in and out, and allocation between crop 1 and 2 to maximize profit s.t. $l_{1,iv} + l_{2,iv} = \bar{l}_{i,iv} + l_{1,iv}^{in} + l_{2,iv}^{in} - l_{iv}^{out}$

# Key Model Predictions

- Effect of increased salinity:
    - Increase in land allocated to aquaculture, increase in farm size concentration
    - The rate of increase decreases in transaction costs
    - Rental market: fewer farmers rent in land and conditional on renting each farmer rents higher amount

# Identification Strategy

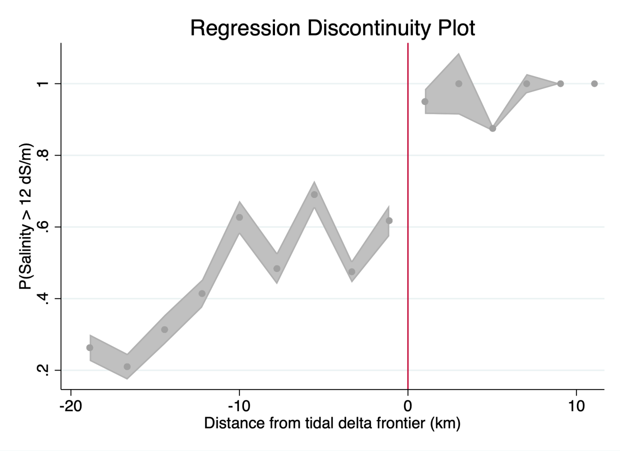
- Challenge: farms with high aquaculture productivity might bring saline water to their field
- Natural variation: tidally active delta vs. mature delta Delta Map
- Network of tidal channels within tidally active delta & semi-diurnal tides flows through the channels
- Tidal water infiltrates into shallow aquifers, capillary movement from aquifers cause soil salinization
- Increase in salinity at the frontier of tidally active delta
- Fuzzy Spatial RD Design: $1\{Within\ \ Tidal\ \ Delta\}_v$ as an instrument for $1\{Salinity > 12dS/m\}_v$
- Threat: direct impact through other differences except salinity: e.g., soil nutrients, flooding

# Fuzzy RD Specification

$$Y_{hv} = \gamma * 1\{Salinity > 12dS/m\} + \beta d_v + \phi d_v * 1\{Salinity > 12dS/m\} + \lambda_l + \epsilon_{hv} \tag{1}$$

- $Y_{hv}$ is the outcome of interest for household $h$ in village $v$
- $d_v$: nearest distance to frontier, positive for villages within tidal delta
- $1\{Salinity > 12dS/m\}_v$: whether the centroid of village $v$ falls within areas with above 12 dS/m salinity
- $N_v = 1\{d_v > 0\}$ as an instrument for $1\{Salinity > 12dS/m\}_v$
- $\lambda_l$: longitude-quartile FE (Ito & Zhang, 2020)
- Local linear, triangular kernel, MSE optimal bandwidth following Calonico et al. (2014)

# Regression Discontinuity Plot



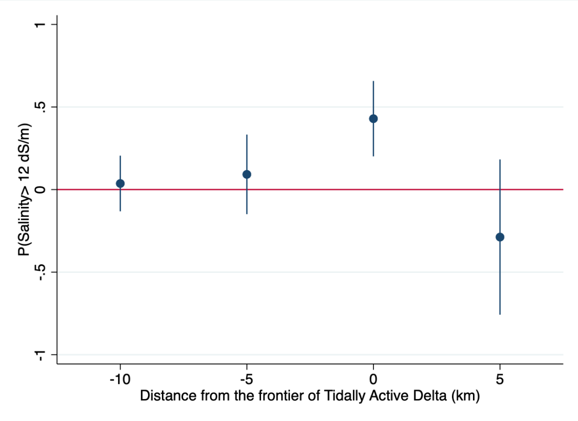
# First Stage Results

| | $1\{Salinity > 12\ dS/m\}$ | |
|---|---|---|
| | RD First Stage | IV First Stage |
| | (1) | (2) |
| $1\{d_v > 0\}$ | $0.429^{***}$ | $0.604^{***}$ |
| | (0.119) | (0.0399) |
| F-Stats | 17 | 228 |
| Longitude quartile FE | Yes | No |
| District FE | No | Yes |
| $N$ | 146 | 2505 |
| Control Mean | 0.38 | 0.38 |
| BW (km) | 6 | NA |

Standard errors in parentheses are clustered at village level
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

- Between 43 to 60 percentage point increase in probability of high salinity

# Placebo Cutoff Test



# Land Reallocation to Aquaculture

| | Amount of Land in Aquaculture (decimals) | | | |
|---|---|---|---|---|
| | Fuzzy RD | | 2SLS | |
| | (1) | (2) | (3) | (4) |
| $1\{Salinity > 12\ dS/m\}$ | 50.68** | 52.27*** | 35.93*** | 31.79*** |
| | (20.57) | (19.50) | (8.602) | (7.834) |
| Longitude quartile FE | Yes | Yes | | |
| District FE | | | Yes | Yes |
| Farm Controls | No | Yes | No | Yes |
| Control Mean | 19 | 19 | 19 | 19 |
| $N$ | 113146 | 113146 | 1166498 | 1166498 |
| BW (km) | 6 | 6 | NA | NA |

Standard errors in parentheses are clustered at village level
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

- Amount of land allocated to aquaculture more than doubles
- Robust to placebo outcomes, placebo cutoff, and different bandwidth choices

# Robustness to Exclusion Threat

- Concern: tidally active delta have direct impact through other permanent differences except salinity: e.g., soil nutrients, flooding

| | Rabi Season Crops | | Rabi Season Rice | | Kharif Season Rice |
|---|---|---|---|---|---|
| | Rice | Wheat | Tolerant Rice | Sensitive Rice | |
| | (1) | (2) | (3) | (4) | (5) |
| $1\{Salinity > 12\ dS/m\}$ | -34.25$^{***}$ | -0.852$^{***}$ | -6.373$^{***}$ | -27.88$^{***}$ | 12.70 |
| | (3.158) | (0.142) | (1.073) | (3.596) | (10.00) |
| District FE | Yes | Yes | Yes | Yes | Yes |
| $N$ | 1166498 | 1166498 | 1166498 | 1166498 | 1166498 |

Standard errors in parentheses are clustered at village level
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

- Reallocated land from Rabi season crop farming
- Impact is greater on the use of salinity sensitive rice varieties
- No effect on Kharif season rice farming

# Effect of Salinity on Farm Size Consolidation: Results

| | Gini Index | |
|---|---|---|
| | Farm Size | Land Ownership |
| | (1) | (2) |
| $1\{Salinity > 12\ dS/m\}$ | 0.114*** | 0.0497 |
| | (0.0155) | (0.0328) |
| District FE | Yes | Yes |
| Control Mean | 0.67 | 0.74 |
| $N$ | 2505 | 2505 |

Standard errors in parentheses are clustered at village level
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

- 17% increase in gini index of farm size
- No evidence of effect on land ownership consolidation
- Potential mechanism: consolidation through land rentals

# Consolidation through Rental Market

| | $1\{Land\ Rented\ in > 0\}$ | Amount rented in | |
|---|---|---|---|
| | | Full Sample | Land rented in$> 0$ |
| | (1) | (2) | (3) |
| $1\{Salinity > 12\ dS/m\}$ | -0.216$^{***}$ | -0.568 | 50.56$^{**}$ |
| | (0.0460) | (6.620) | (20.10) |
| District FE | Yes | Yes | Yes |
| Farm Controls | Yes | Yes | Yes |
| $N$ | 1166498 | 1166498 | 373006 |
| Control Mean | 0.35 | 20.27 | 60.23 |

Standard errors in parentheses are clustered at village level
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

- 61 % decrease in the number of households who rent-in land
- Conditional on renting, amount of land rented-in increases by 83%
- Robustness: no evidence of differential rental activities for housing

# Friction: Rental Contract Enforcement between Religious Groups

- Renters make large fixed investment$\rightarrow$ need contract enforcement
- Enforcement through court is generally infeasible
- Settlement of disputes by local leaders: ward councilors and chairperson of union council
- Two major religious groups: Muslims & Hindus
- Fixed location of land parcels $\rightarrow$ rental contracts between religious groups are required
- Local leaders' potential incentive: winning elected offices
  - higher diversity $\rightarrow$ needs votes from both groups $\rightarrow$ lower discrimination
  - lower diversity $\rightarrow$ might discriminate in favor the dominant religion

# Religious diversity and adaptation

- Effect of lower religious diversity is ambiguous:
  - Poorer contract enforcement $\rightarrow$ minority group less likely to rent out $\rightarrow$lower adaptation
  - Dominant group might appropriate lands from minorities $\rightarrow$ more adaptation
- Religious Diversity Index of village $v$=$(1 - (X_v^2 + Y_v^2)) * 100$
- Current religious distribution is endogenous: use diversity index of 1961 as an instrument
- Threat: direct effect of diversity through other channels, e.g., institution and public good provision

# Impact of religious diversity on land reallocation

| | Amount of Land in Aquaculture (decimals) | |
|---|---|---|
| | (1) | (2) |
| $1\{Salinity > 12\ dS/m\}$ | 23.64** | 26.26** |
| | (9.308) | (9.759) |
| $1\{Above\ Median\ Diversity\}$ | -3.323 | |
| | (6.314) | |
| $1\{Salinity > 12\ dS/m\}$*$1\{Above\ Median\ Diversity\}$ | 22.62** | |
| | (10.60) | |
| $1\{Above\ Median\ Diversity\ in\ 1961\}$ | | -2.652 |
| | | (14.17) |
| $1\{Salinity > 12\ dS/m\}$*$1\{Above\ Median\ Diversity\ in\ 1961\}$ | | 28.76** |
| | | (10.76) |
| $N$ | 1166439 | 1166498 |
| Cluster | Village | Sub-district |

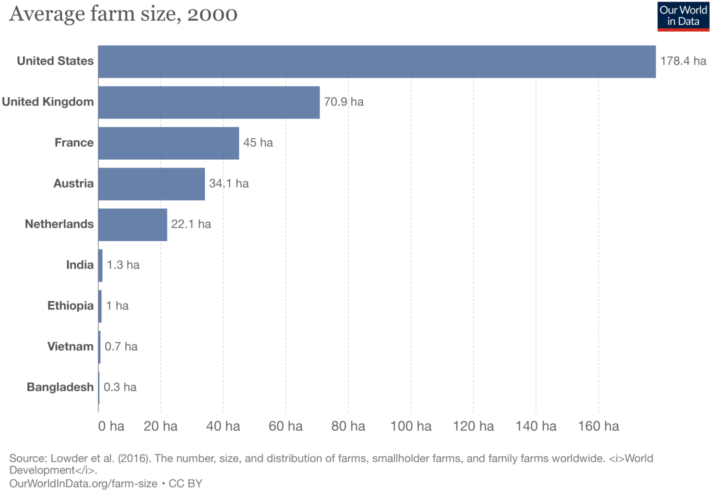
$^{*}\ p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$

- Higher religious diversity almost doubles the extent of adaptation
- Robustness: no evidence of direct effect on use of tap water and sanitary toilets, no effect of salinity on religious composition
- Back of the envelope estimation: annual loss of approx. $450 in farm income per household, 35% of mean annual income

# Conclusion

- Costinot et al. (2016) provides optimism for climate change adaptation
- Frictions in developing countries limit the process of land reallocation
- Implications: can potentially cause divergence between rich and poor countries
- A research agenda: identifying specific frictions in adaptation and generate evidence base on scalable solutions

# Farm Size Comparison

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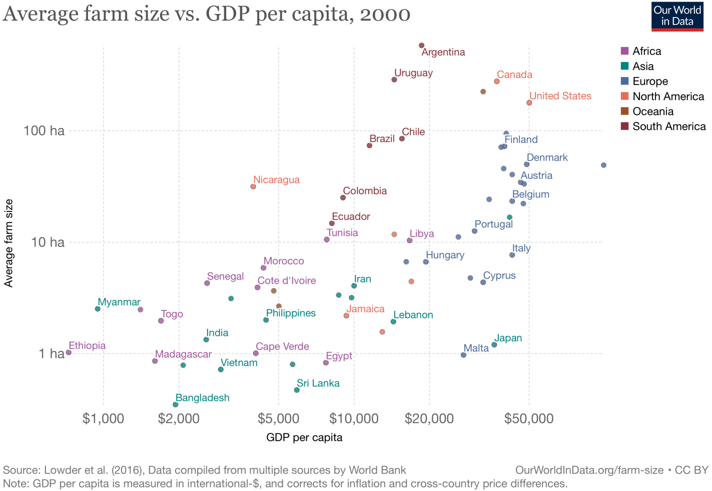
# Farm Size vs. GDP

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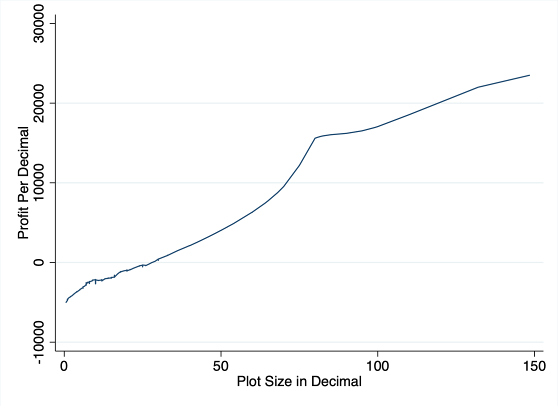
# Minimum Scale in Aquaculture

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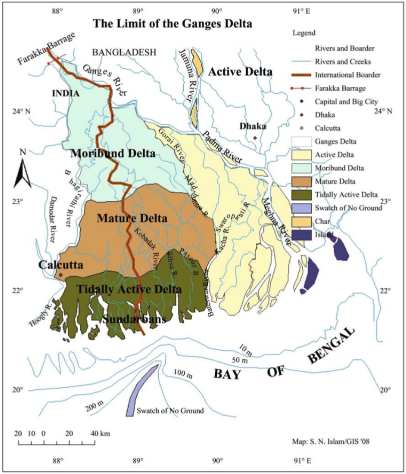
# Tidally Active Delta




back *Source: Islam and Gnauck (2008)*