CLIMATE CHANGE IMPACT ON RICE PRODUCTION AND ADAPTATION: A CASE STUDY OF SALINITY INTRUSION IN COASTAL AREAS OF THE MEKONG DELTA, VIETNAM

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This project funded by SEARCA

Online

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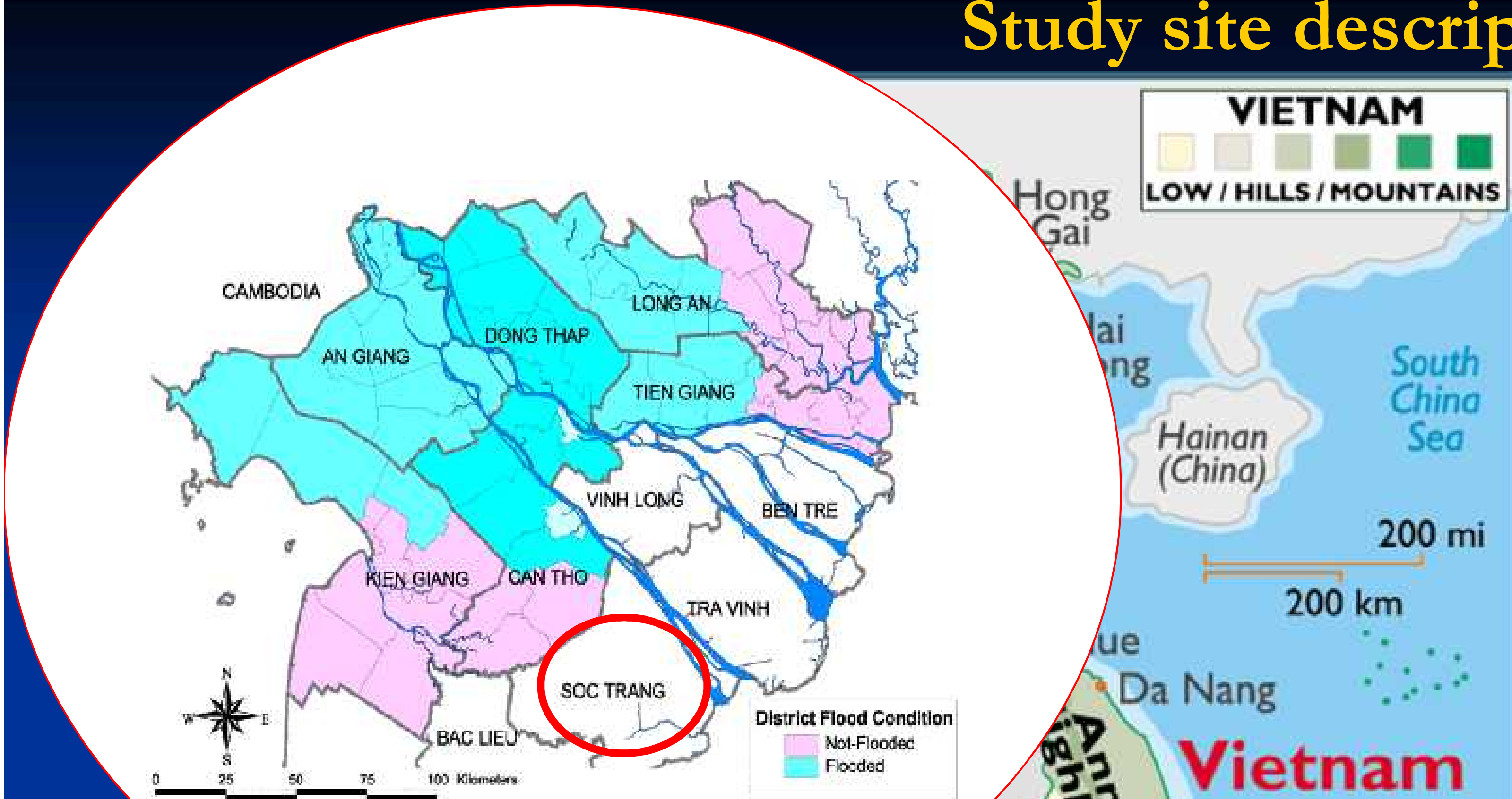
Introduction

- Climate change has become one of the major threats
- Vietnam is one of five countries that may be the most seriously affected by global climate change and a consequent rise in sea level
- Salinity lands in the Mekong Delta region are relatively large compared to the whole country
- Although there have been many studies on evaluating the effects of salinity intrusion in rice production, no studies have evaluated specific statistics about the decline of rice production


CAMBODIA
AN GIANG
DONG THAP
LONG AN
TIEN GIANG


VIETNAM
LOW / HILLS / MOUNTAINS
China
Red River
Hong Gai
Dien Bien Phu
Hanoi
Hai Phong
Gulf of Tonkin
Hainan (China)
South China Sea
Vinh
200 mi
200 km
Hue
Da Nang
Annam Highlands
Vietnam
Qui Nhon
Nha Trang
Cam Ranh
Ho Chi Minh
(Saigon)
Mekong Delta
Pacific Ocean

Study site description



- By mid-March 2016, all 13 provinces in the Mekong Delta were seriously affected by the most severe drought and saline intrusion in the past 100 years.

Mekong Delta farmers grapple with worst saline intrusion

VNA Monday, March 07, 2016 - 15:04:48 Print

A rice field in Lich Hoi Thuong commune of Soc Trang province dies of saltwater intrusion (Photo: VNA)

Can Tho (VNA) – Mekong Delta farmers are struggling with the worst water shortages and saltwater intrusion in nearly a century.

The Mekong Delta has nearly 4 million hectares of farmland, accounting for almost 30 percent of Vietnam's total farmland area, with over 50 percent under rice.

A rice field in Tran De district of Soc Trang province dies of saltwater intrusion

Data Collection

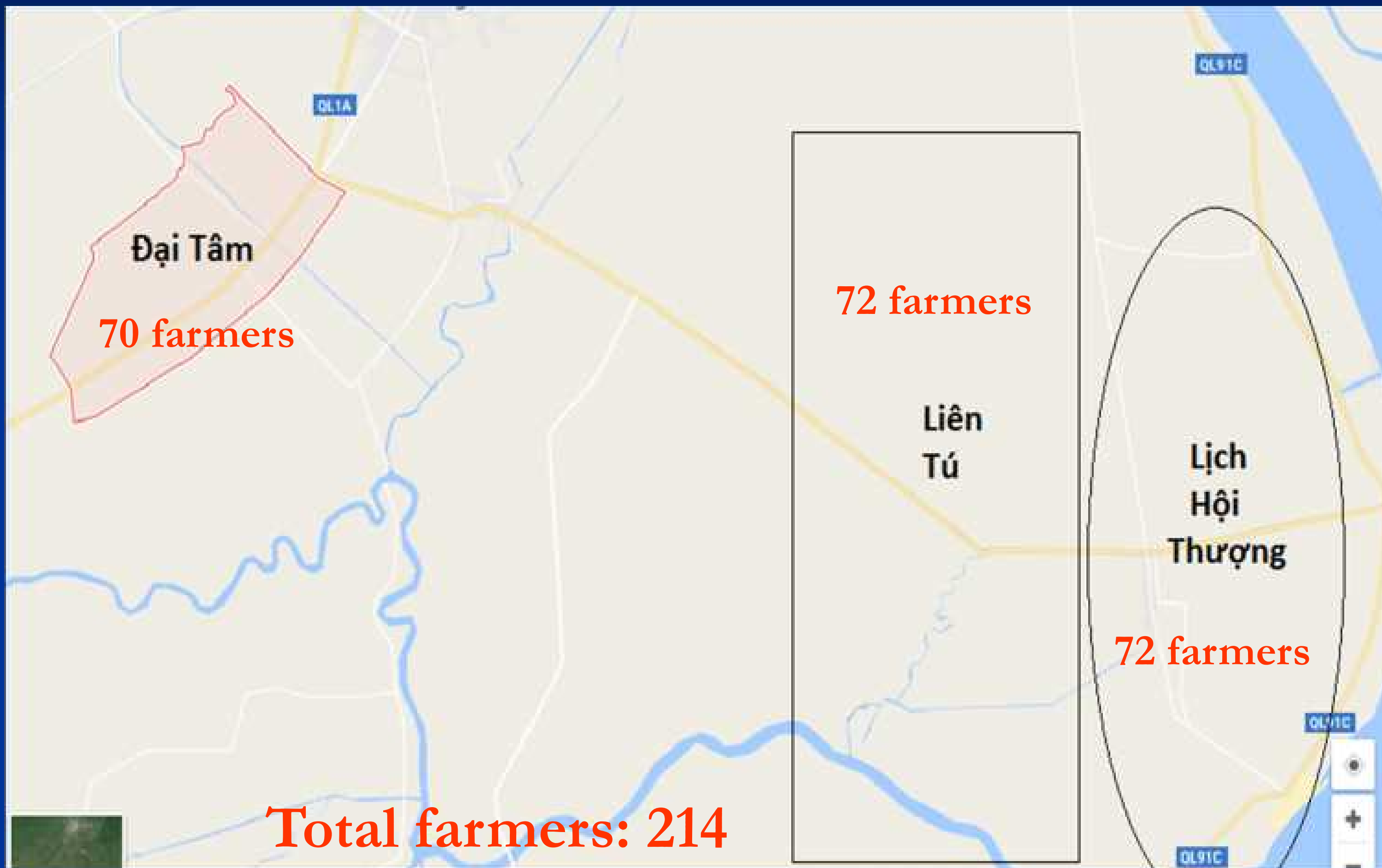


Figure 1. Map showing study site.

Study site description

Table 1. The situation of Salinity in the study areas in 2016

	Unit	Non-salinity area (Dai Tam)	Area of Salinity 1 (Lieu Tu)	Area of Salinity 2 (Lich Hoi Thuong)
Period of salinity	month	December 12, 2015 – February 2, 2016		
Average level of salinity	‰	0.0 – 0.3	0.8-2.8	1.7-2.8

Source: The statistic office of My Xuyen and Tran De, 2016

Table 2. Farmers' perception on salinity in study areas

	Non-salinity area (Dai Tam)		Area of Salinity 1 (Lieu Tu)		Area of Salinity 2 (Lich Hoi Thuong)	
	Number	Percent (%)	Number	Percent (%)	Number	Percent (%)
Rice production is not affected by salinity	69	98.57	2	2.78	3	4.17
Rice production is affected by salinity	1	1.43	70	97.22	69	95.83
Total	70	100	72	100	72	100

Source: Own estimates; data appendix available from authors.

Methodology

Concept for estimating economic loss caused by salinity intrusion

$$®_{salinity} = \left(\bar{P} - \Delta P\right)\left(\bar{Q} - \Delta Q\right) - \left(\bar{C} + \Delta C\right)$$

$$= \bar{P}\bar{Q} - \bar{P} \times \Delta Q - \Delta P \times \bar{Q} + \Delta P \times \Delta Q - \bar{C} - \Delta C$$

$$= \left(\bar{P}\bar{Q} - \bar{C}\right) - \left(\bar{P} \times \Delta Q + \Delta P \times \bar{Q} + \Delta \bar{C}\right) + \Delta P \times \Delta Q$$

$$= \quad ®_{non-salinity} \quad - \quad \text{Profit loss}$$

$$\Rightarrow \text{Profit loss} = \bar{P} \times \Delta Q \quad + \quad \Delta P \times \bar{Q} \quad + \quad \Delta \bar{C}$$

$$= \text{Quantity loss} + \text{Quality loss} + \text{Cost increase}$$

$\pi_{non\text{-}salinity}$ and $\pi_{salinity}$ are the rice profits in the non-salinity and salinity areas.

$\Delta P \times \Delta Q$ is small compared with the other parts of the equation, it can be ignored and assumed to be 0

Quantity loss

- **Production function approach**:

$$Y = f(L, K, I, Z, E, D_1, D_2)$$

  - *Y* is the rice yield of a farmer in the studied year (tones/ha)
  - L is the number of labors for rice cultivation (man-days/ha)
  - K is capital input (1,000VND/ha)
  - I is a vector of material inputs as seeds (kg/ha), fertilizers (kg/ha), herbicide (ml/ha) and pesticides (ml/ha)
  - Z is a vector of social-economic characteristics of farmers
  - E is vector of farming conditions and environmental factors
  - D1, D2 are the relative location of farms (D1=1 if the farmers in Lieu Tu which is considered as the area little affected by salinity, D2= 1 if the farmers in Lich Hoi Thuong which is considered as the area heavily affected by salinity; D1 = 0 and D2 = 0 if the farmers in Dai Tam which is considered as the area unaffected by salinity)

Quantity loss

- **The reduced yield of rice is defined as:**

$$\Delta Y_1 = f(\bar{L}, \bar{K}, \bar{I}, \bar{Z}, \bar{E}, D_1 = 0, D_2 = 0) - f(\bar{L}, \bar{K}, \bar{I}, \bar{Z}, \bar{E}, D_1 = 1, D_2 = 0)$$

$$\Delta Y_2 = f(\bar{L}, \bar{K}, \bar{I}, \bar{Z}, \bar{E}, D_1 = 0, D_2 = 0) - f(\bar{L}, \bar{K}, \bar{I}, \bar{Z}, \bar{E}, D_1 = 0, D_2 = 1)$$

- **The translog production functional form:**

$$\ln(Y) = \sim_0 + \sim_1 \ln(L) + \sim_2 \ln(K) + \sim_3 \ln(I) + \frac{1}{2}\sim_{11}\left(\ln(L)\right)^2 + \sim_{12}\ln(L)\ln(K) + \sim_{13}\ln(L)\ln(I) +$$

$$+\frac{1}{2}\sim_{22}\left(\ln(K)\right)^2 + \sim_{23}\ln(K)\ln(I) + \frac{1}{2}\sim_{33}\left(\ln(I)\right)^2 + \sum_{k=1}^{5} {}_k Z_k + \sum_{h=1}^{3} ¢_h E_h + ¥_1 D_1 + ¥_2 D_2 + £$$

- **Check the constant returns to scale:**

$$\sim_1 + \sim_2 + \sim_3 = 1; \sim_{11} + \sim_{12} + \sim_{13} = 0$$

$$\sim_{12} + \sim_{22} + \sim_{23} = 0; \sim_{13} + \sim_{23} + \sim_{33} = 0$$

- **Test the existence of Cobb-Douglass function:**

$$\sim_{11} = \sim_{12} = \sim_{13} = \sim_{22} = \sim_{23} = \sim_{33} = 0$$

Cost increase

- **Replacement cost approach** :

$$C = C(W_s, W_h, W_f, W_p, Y, Z, E, D_1, D_2)$$

  - *C* is the total cost of a farmer (VND/ha),
  - W_s is the price of seed (VND/kg),
  - W_h is the price of herbicide (VND/100ml), W_f is the price of fertilizers (VND/kg),
  - W_p is the price of pesticides (VND/100ml),
  - *Y* is the rice yield of a farmer in the studied year (tones/ha),
  - *Z* is a vector of social-economic characteristics of farmers,
  - *E* is a vector of farming conditions,
  - D_1, D_2 are the relative location of farms (D_1=1 if the farmers in Lieu Tu which is considered as the area little affected by salinity, D_2= 1 if the farmers in Lich Hoi Thuong which is considered as the area heavily affected by salinity; D_1 = 0 and D_2 = 0 if the farmers in Dai Tam which is considered as the area unaffected by salinity)

Cost increase

- The increase in input costs :

$$\Delta C_1 = C(\bar{W}_s, \bar{W}_h, \bar{W}_f, \bar{W}_p, \bar{Y}, \bar{Z}, \bar{E}, D_1 = 1, D_2 = 0) - C(\bar{W}_s, \bar{W}_h, \bar{W}_f, \bar{W}_p, \bar{Y}, \bar{Z}, \bar{E},, D_1 = 0, D_2 = 0)$$

$$\Delta C_2 = C(\bar{W}_s, \bar{W}_h, \bar{W}_f, \bar{W}_p, \bar{Y}, \bar{Z}, \bar{E}, D_1 = 0, D_2 = 1) - C(\bar{W}_s, \bar{W}_h, \bar{W}_f, \bar{W}_p, \bar{Y}, \bar{Z}, \bar{E},, D_1 = 0, D_2 = 0)$$

- The Cobb-Douglas cost functional form:

$$\ln(C) = \text{¨}_0 + \text{¨}_1 \ln(W_s) + \text{¨}_2 \ln(W_h) + \text{¨}_3 \ln(W_f) + \text{¨}_4 \ln(W_p) + \text{¨}_5 \ln(Y) +$$

$$+ \sum_{k=1}^{4} {}_k Z_k + \sum_{h=1}^{3} \text{¢}_h E_h + \text{¥}_1 D_1 + \text{¥}_2 D_2 + \text{£}$$

Profit loss

Profit function approach:

$$\pi^* = \pi\left(W^*, C, Z, E, D_1, D_2\right)$$

- π^* is normalized profit defined as gross revenue minus variable cost divided by farm-specific output price,
- W^* is a vector of variable input prices divided by output price,
- C is a vector of fixed factors of the farm,
- Z is a vector of social-economic characteristics of farmers,
- E is a vector of farming conditions, and
- D_1, D_2 are the relative location of farms (D_1=1 if the farmers in Lieu Tu which is considered as the area little affected by salinity, D_2= 1 if the farmers in Lich Hoi Thuong which is considered as the area heavily affected by salinity; D_1 = 0 and D_2 = 0 if the farmers in Dai Tam which is considered as the area unaffected by salinity) The loss of net economic return:

Profit loss

- The profit loss :

$$\Delta ®_1 * = ® \left(\bar{W}*, \bar{C}, \bar{Z}, \bar{E}, D_1 = 0, D_2 = 0 \right) - ® \left(\bar{W}*, \bar{C}, \bar{Z}, \bar{E}, D_1 = 1, D_2 = 0 \right)$$

$$\Delta ®_2 * = ® \left(\bar{W}*, \bar{C}, \bar{Z}, \bar{E}, D_1 = 0, D_2 = 0 \right) - ® \left(\bar{W}*, \bar{C}, \bar{Z}, \bar{E}, D_1 = 0, D_2 = 1 \right)$$

- The translog profit functional form:

$$® * = \sim_0 + \sum_{j=1}^{4} \sim_j \ln W_j * + \frac{1}{2} \sum_{j=1}^{4} \sum_{k=1}^{4} ²_{jk} \ln W_j * \ln W_k * + \sum_{j=1}^{4} \sum_{l=1}^{2} ¤_{jl} \ln W_j * \ln C_l +$$

$$+ \sum_{l=1}^{2} {}_l \ln C_l + \frac{1}{2} \sum_{l=1}^{2} \sum_{t=1}^{2} ¨_{lt} \ln C_l \ln C_t + \sum_{m=1}^{3} ´_m Z_m + \sum_{n=1}^{3} ¦_n E_n + ¥_1 D_1 + ¥_2 D_2 + £$$

- Test the existence of Cobb-Douglass function:

$$²_{jk} = ¤_{jl} = ¨_{lt} = 0$$

Lagrange Multiplier (LM) tests for heteroscedasticity

$$LM = nR^2 \sim \chi^2_k$$

n is the number of observations

R^2 is the R-Square of $|\hat{u}_i| = \tilde{\alpha}_0 + \tilde{\alpha}_1 X_{1i} + \tilde{\alpha}_2 X_{2i} + ... + \tilde{\alpha}_k X_{ki} + \tilde{v}_i$

k is the number of restricted factors

Correlation matrix method for multicollinearity

Correlations in independent variables must be less than 70%

Results and discussion

Table 3. Descriptive statistics of rice production per hectare a year

	Non-salinity (1)	Salinity 1 (2)	Salinity 2 (3)	Difference (1) vs. (2)	Difference (1) vs. (3)
Rice yield (tons)	13.61	11.49	8.67	2.13***	4.94***
Output price (Thousand VND)	10.16	9.51	8.00	0.646*	2.15***
Family labor (days)	23.18	30.15	20.19	-6.97*	2.98ns
Capital (Thousand VND)	11,452	11,816	11,118	-363.6ns	334.2ns
Seed (kg)	293.14	388.53	383.2	-95.4***	-90.07***
Herbicide (ml)	2.940.74	2.331.15	2.186.8	609.59ns	753.94**
Fertilizer (kg)	1,145.62	1,128.8	1,056.2	16.86ns	89.43ns
Pesticide (ml)	5,203.14	6,784.61	6,348.2	-1,581.5*	-1,145.1ns
Training (1=yes, 0=no)	0.64	0.46	0.42	0.18*	0.23*
Gender (1=male, 0=female)	0.89	0.90	0.81	-0.02ns	0.08ns

*Notes: ns: no significant; ***, **, * indicate statistical significance at the 0.01, 0.05 and 0.1 level respectively*
Source: Own estimates; data appendix available from authors.

Table 3. Descriptive statistics of rice production per hectare a year

	Non-salinity (1)	Salinity 1 (2)	Salinity 2 (3)	Difference (1) vs. (2)	Difference (1) vs. (3)
Family member (persons)	4.37	4.57	4.85	-0.198ns	-0.48**
Age (years)	49.6	46.08	46.5	3.52**	3.1ns
Experience (years)	28.21	26.94	26.35	1.27ns	1.87ns
Rice area (ha)	2.20	1.86	1.56	0.34ns	0.64*
Diseases (1=yes, 0=no)	0.41	0.44	0.57	-0.03ns	-0.155*
Soil quality (1 = Vey no-fertile, 2 = no-fertile, 3 = Medium, 4 = Fertile, and 5 = Very fertile)	3.41	2.94	2.71	0.47***	0.71***
Irrigation (1 = located in the irrigation region, 0 = Otherwise)	0.700	0.778	0.792	-0.078ns	-0.092ns

*Notes: ns: no significant; ***, **, * indicate statistical significance at the 0.01, 0.05 and 0.1 level respectively*

Source: Own estimates; data appendix available from authors.

Table 11. The OLS regression of rice profit function

Variables	Coef.	Robust Std. Err.	Variables	Coef.	Robust Std. Err.
$\ln(I_s)\ln(I_p)$	-0.160^{***}	0.091	Z_1	0.023^{ns}	0.039
$\ln(I_s)\ln(L)$	0.0114^{ns}	0.043	Z_2	0.000823^{ns}	0.0015
$\ln(I_s)\ln(K)$	0.147^{ns}	0.294	Z_3	-0.013^{ns}	0.024
$\ln(I_w)\ln(I_f)$	-0.0016^{ns}	0.076	Z_4	0.059*	0.029
$\ln(I_w)\ln(I_p)$	0.009^{ns}	0.031	Z_5	0.015^{ns}	0.013
$\ln(I_w)\ln(L)$	-0.024^{ns}	0.020	E_1	-0.087***	0.036
$\ln(I_w)\ln(K)$	-0.263^{ns}	0.181	E_2	0.141***	0.045
$\ln(I_f)\ln(I_p)$	0.017^{ns}	0.073	E_3	0.076***	0.033
$\ln(I_f)\ln(L)$	-0.078^{ns}	0.050	**D_1**	**-0.203*** **	**0.044**
$\ln(I_f)\ln(K)$	0.313^{ns}	0.316	**D_2**	**-0.353*** **	**0.050**
$\ln(I_p)\ln(L)$	0.050***	0.020	Constant	-4.320	60.730
R-square			0.64		
F-statistic			14.14		

*Notes: ***, **, * indicate statistical significance at the 0.01, 0.05 and 0.1 level respectively*

Source: Own estimates; data appendix available from authors.

Table 10. The OLS regression of rice cost function

Variables	Symbol	Coef.	Robust St.Er.
ln(Price of seed)	$\ln(W_s)$	0.1327***	0.0208
ln(Price of herbicide)	$\ln(W_w)$	0.1212**	0.0606
ln(Price of fertilizer)	$\ln(W_f)$	0.0183	0.0612
ln(Price of pesticide)	$\ln(W_p)$	-0.0375	0.0269
ln(Yield)	$\ln(Y)$	0.2053***	0.0510
Age	Z_1	0.0007	0.0011
Highschool	Z_2	0.0346	0.0312
Training	Z_3	-0.0331	0.0233
Family members	Z_4	-0.0069	0.0115
Irrigation	E_1	-0.0075	0.0264
Soil quality	E_2	-0.0258*	0.0156
Disease	E_3	0.0403*	0.0242
Salinity 1	**D1**	**0.0810*** **	**0.0303**
Salinity 2	**D2**	**0.0458**	**0.0378**
Constant		9.4719***	0.2755
R-square		0,25	

Table 11. The OLS regression of rice profit function

Variables	Symbol	Coef.	Robust St.Er.
…	…	…	…
Age	Z_1	9.53	15.94
Highschool	Z_2	-140.29	543.48
Training	Z_3	492.17	378.75
Disease	E_1	-523.28	394.14
Soil quality	E_2	943.02***	306.84
Irrigation	E_3	905.78**	445.12
Salinity 1	**D1**	**-2,010.43*** **	**486.93**
Salinity 2	**D2**	**-3,287.04*** **	**606.61**
Constant		191,484.50	852,974.40
R-square		0.63	
Included observation		214	

*Notes: ***, **, * indicate statistical significance at the 0.01, 0.05 and 0.1 level respectively*
Source: Own estimates; data appendix available from authors.

Table 5. Reduced yield in rice farming caused by salinity

	Reduced yield (Tons/ha)	Percentage of reduced yield (%)
Salinity 1 vs. Non-salinity area	2.502	18.382
Salinity 2 vs. Non-salinity area	4.051	29.765

Conclusion

- The null hypothesis of constant returns to scale is rejected
- The Cobb-Douglass formal existence of production function is rejected
- Yield loss is about 2.5 – 4.05 tons per hectare and annual the profit loss was about VND 9.3 - 15.1 million tons per hectare
- Applying the intercropping system instead of current mono-cultivation to increase soil fertility and limit pest and diseases.
- Agricultural extensions and local authorities should regularly measure the salinity level of water resources
- Strengthen embankments and dams to store fresh water when saltwater intrusion occurs.


Thank you very much
for your attention