Empowerment, climate change adaptation and agricultural production: evidence from Niger

Fleur Wouterse

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
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Motivation

- Climate change poses potentially large risks for farmers in the developing world as it could exacerbate climate variability and extreme events
- Smallholders in drought-prone Niger have long adjusted their management practices to address negative impacts of climate.
- Zaï pits, small holes (diameter 20–40 cm and depth 10–20 cm) filled with compost and planted with seeds constitute an important adaptative strategy
- An understanding of drivers and obstacles to zaï pit adoption and returns to agricultural production is critical:
  - to facilitate and enhance adaptation to climate change
  - for developing well-targeted policies.

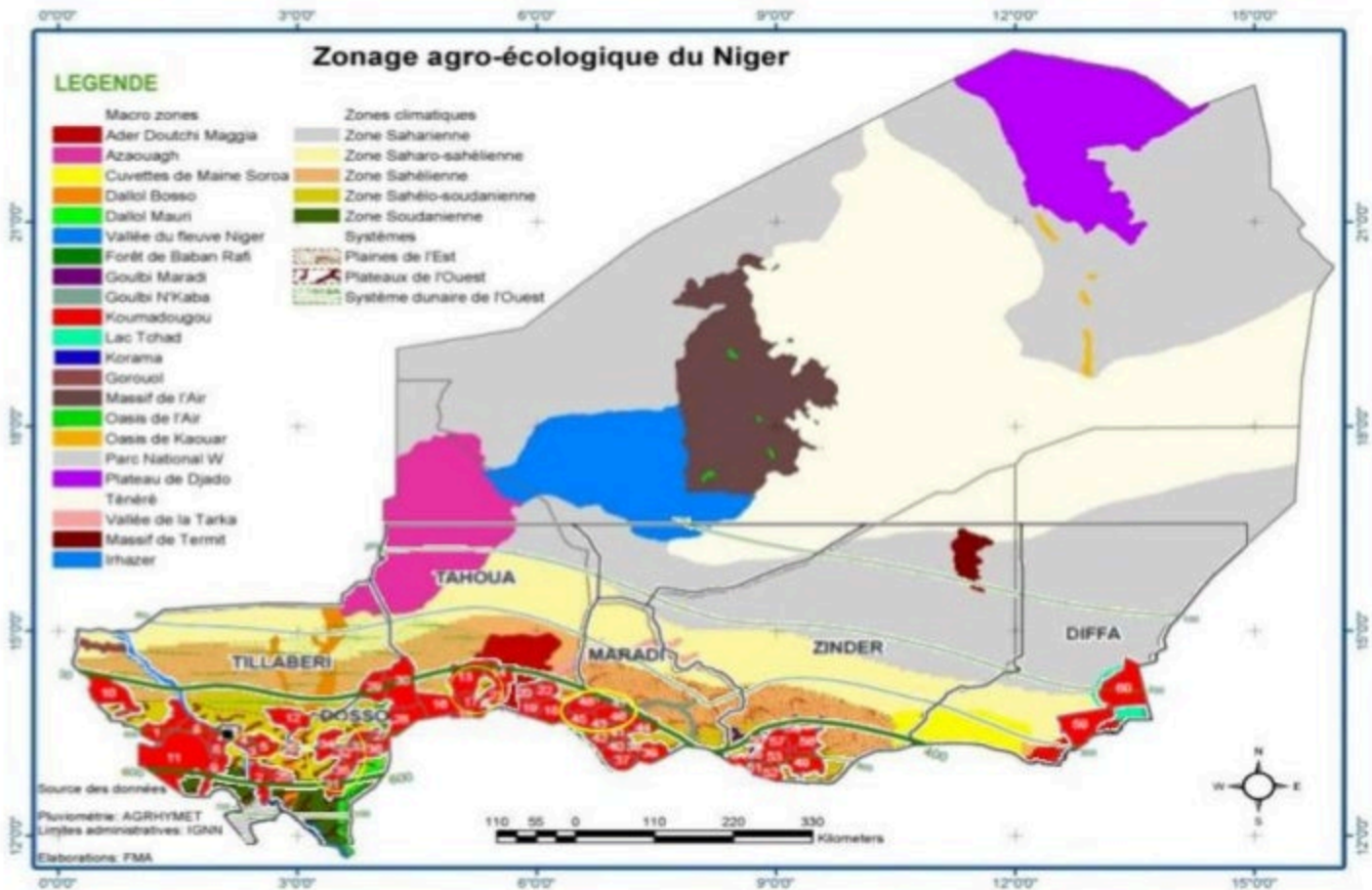
Motivation

- Considerable research exists on adaptation strategies (see Burnham and Ma 2016 for an overview) but empirical evidence is lacking on:
  1) The role that climate change perception plays in adaptation
  2) The importance of human capital aspects (empowerment) in the decision to adapt
- Here we use new household-level data from the Tahoua region and model adaptation decision-making and returns to adaptation at the farm household level.

Data

- Data collected in May-June 2015 for 500 randomly sampled households in 35 villages situated in three communes (Doguéraoua, Malbaza, and Tsernaoua) in the Maggia valley of the Birni N'Konni Department in the Tahoua region.
- Household-level data collected using a standard agricultural household survey Individual-level empowerment data collected using the standard Women's Empowerment in Agriculture Index (WEAI) survey
- Rain-fed agriculture (millet and sorghum cultivation) is the primary source of food and income
- Agriculture is predominantly rainfed, and yields rely on one rainy season (May to September)

Figure 1 Map of Niger



Data

Table 1 The domains, indicators, and weights in the WEAI

Domain	Indicator	Definition of indicator	Weight
Production	Input in productive decisions	Sole or joint decision-making over food, cash crop farming, livestock, and fisheries	1/10
	Autonomy in production	Autonomy in agricultural production	1/10
Resources	Ownership of assets	Sole or joint ownership of major household assets	1/15
	Purchase, sale or transfer of assets	Whether respondent participates in decision to buy, sell, or transfer his/her owned assets	1/15
	Access to and decisions on credit	Access to and participation in decision-making concerning credit	1/15
Income	Control over use of income	Sole or joint control over income and expenditures	1/5
Leadership	Group member	Whether respondent is an active member in a group	1/10
	Speaking in public	Whether the respondent is comfortable speaking in public	1/10
Time	Workload	Allocation of time to productive and domestic tasks	1/10
	Leisure	Satisfaction with the time available for leisure activities	1/10

Source: Alkire et al. (2013)

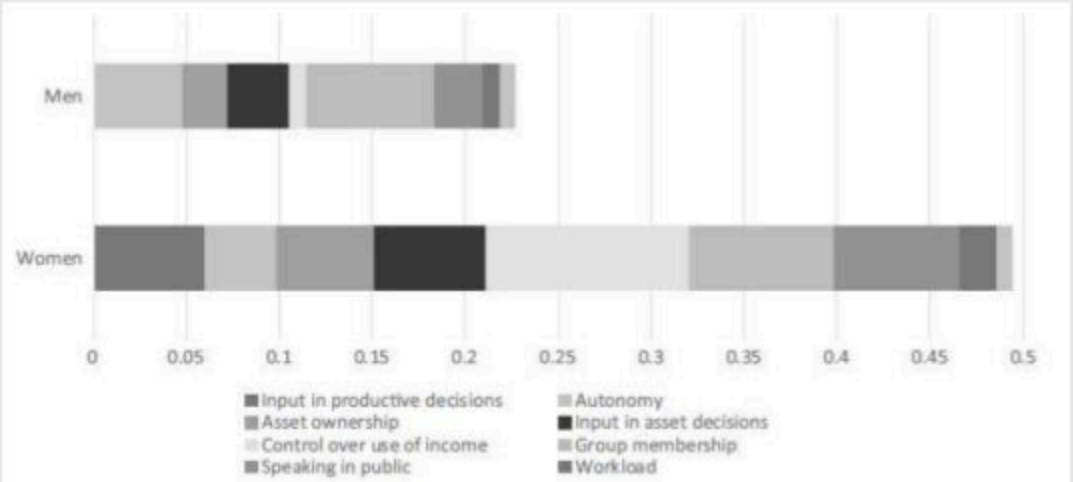


Figure 1 Contributors to inadequacy in empowerment

Model

- The zaï adoption decision as a function of drought perception and human capital and its implications for productivity can be modeled in two-stages
- In the first stage, we use a selection model for zaï adoption where a representative risk-averse farm household chooses to implement the pits if it generates net benefits.
- Net benefits from zaï adoption represented by a latent variable D_j^* is a function of the observed characteristics and attributes, Z, in a latent variable model:

$$D_j^* = \gamma Z_j + \varepsilon_j \text{ with } D_j = \begin{cases} 1, if\, D_j^* > 0 \\ 0, otherwise \end{cases} \quad (1)$$

Model

- In the second stage, we model the effect of adoption on productivity via a representation of the production technology.
- The endogenous switching regression approach as a generalization of Heckman's accounts for selection on unobservables by treating selectivity as an omitted variable problem
- Regimes are defined as follows:

$$Regime\ 0\ (Not\ adopt): Y_{Nj} = X_{Nj}\beta_N + u_{Nj} \text{ if } D_j = 0 \quad (2a)$$

$$Regime\ 1\ (Adopt): Y_{Aj} = X_{Aj}\beta_A + u_{Aj} \text{ if } D_j = 1 \quad (2b)$$

- The error term of the selection equation is correlated with the error terms of the productivity functions and the expected values of u_{Aj} and u_{Nj}

$$E\left(u_{Aj}\middle|D=1\right) = \sigma_{A\varepsilon}\rho_A \frac{\varphi(\mathbf{Z}_{j\gamma})}{\Phi(\mathbf{Z}_{j\gamma})} \text{ and } E\left(u_{Nj}\middle|D=0\right) = -\sigma_{N\varepsilon}\rho_N \frac{\varphi(\mathbf{Z}_{j\gamma})}{1-\Phi(\mathbf{Z}_{j\gamma})}$$

- φ is the probability density and Φ is the cumulative distribution function and ρ's are correlation coefficients, σ's covariances

Model

- The conditional expectation of yields for households that adopted:

$$E(Y_{Aj}|D=1) = X_{Aj}\beta_A + \sigma_{A\varepsilon}\rho_A \frac{\varphi(\mathbf{Z}_{j\gamma})}{\Phi(\mathbf{Z}_{j\gamma})} \quad (3a)$$

- The expected output had the household chosen not to adopt:

$$E(Y_{Nj}|D=0) = X_{Nj}\beta_N - \sigma_{N\varepsilon}\rho_N \frac{\varphi(\mathbf{Z}_{j\gamma})}{1-\Phi(\mathbf{Z}_{j\gamma})} \quad (3b)$$

- Expected yields in the hypothetical counterfactual case that the non-adopted farm household adopted are given by:

$$E(Y_{Aj}|D=0) = X_{Aj}\beta_A - \sigma_{A\varepsilon}\rho_A \frac{\varphi(\mathbf{Z}_{j\gamma})}{1-\Phi(\mathbf{Z}_{j\gamma})} \quad (3c)$$

- Expected yields in the hypothetical counterfactual case that the non-adopted farm household adopted are given by:

$$E(Y_{Nj}|D=1) = X_{Nj}\beta_N + \sigma_{N\varepsilon}\rho_N \frac{\varphi(\mathbf{Z}_{j\gamma})}{\Phi(\mathbf{Z}_{j\gamma})} \quad (3d)$$

Model

- The average treatment effect on the treated (TT)

$$TT = E\left[Y_{Aj}\middle|D=1\right] - E\left[Y_{Nj}\middle|D=1\right] = \mathbf{X}_{Aj}(\beta_A - \beta_N) + (\sigma_{A\varepsilon}\rho_A - \sigma_{N\varepsilon}\rho_N)\frac{\varphi(\mathbf{Z}_j\gamma)}{\Phi(\mathbf{Z}_j\gamma)} \quad (4)$$

- Effect of treatment on the untreated (TU) for the farm households that did not adopt:

$$UT = E\left[Y_{Aj}\middle|D=0\right] - E\left[Y_{Nj}\middle|D=0\right] = \mathbf{X}_{Nj}(\beta_A - \beta_N) + (\sigma_{A\varepsilon}\rho_A - \sigma_{N\varepsilon}\rho_N)\frac{\varphi(\mathbf{Z}_j\gamma)}{1-\Phi(\mathbf{Z}_j\gamma)} \quad (5)$$

- Heterogeneity effects for adopters:

$$BH_A = E\left[Y_{Aj}\middle|D=1\right] - E\left[Y_{Aj}\middle|D=0\right] = \beta_A\left(\mathbf{X}_{Aj} - \mathbf{X}_{Nj}\right) + \sigma_{A\varepsilon}\rho_A\left(\frac{\varphi(\mathbf{Z}_j\gamma)}{\Phi(\mathbf{Z}_j\gamma)} - \frac{\varphi(\mathbf{Z}_j\gamma)}{1-\Phi(\mathbf{Z}_j\gamma)}\right) \quad (6)$$

- Heterogeneity effects for non-adopters

$$BH_N = E\left[Y_{Nj}\middle|D=1\right] - E\left[Y_{Nj}\middle|D=0\right] = \beta_N\left(\mathbf{X}_{Aj} - \mathbf{X}_{Nj}\right) + \sigma_{N\varepsilon}\rho_N\left(\frac{\varphi(\mathbf{Z}_j\gamma)}{\Phi(\mathbf{Z}_j\gamma)} - \frac{\varphi(\mathbf{Z}_j\gamma)}{1-\Phi(\mathbf{Z}_j\gamma)}\right) \quad (7)$$

Estimation strategy

- We use full-information maximum likelihood to simultaneously fit the binary and continuous part of our model to yield consistent standard errors
- Selection instruments:
    1. binary variable that takes the value of 1 if the household perceives increased frequency of drought over the 5 years preceding the survey and
    2. village-level variables that capture dedication to agriculture and lagged availability of financial resources.
- Empowerment is likely to be endogenous to the production process due to simultaneous effects.
    1. difference between the primary male and female in the capacity to be interviewed alone as assessed by the household
    2. binary variable that takes the value of 1 if the household had indicated to have had access to generic information transmitted via the radio.

Estimation strategy

- Levels of variable inputs (seed, labor, and fertilizer) could also be simultaneously determined with current output because a disturbance in the production equation for example a late start of the rainy season could affect output but also levels of input.
- We postulate that variable inputs are determined for the current period by household maximization with respect to anticipated output. Because any shifts in the production relation affect actual but not anticipated output, when these shifts occur, the level of input is unaffected

Results

Endogenous switching regression results for adoption and impact of adoption on cereal yields

	OLS Cereal yield (kg/ha)	IV Cereal yield (kg/ha)	Adoption	Zai = 0 Cereal yield (kg/ha)	Zai = 1 Cereal yield (kg/ha)
Zai (1 = yes)	47.33 (21.14)[b]**	43.99 (22.30)*			
Household labor (days/ha)	4.77 (0.77)**	4.69 (0.78)**		4.34 (0.90)**	6.86 (1.95)**
Household labor squared (/100)	− 2.44 (0.42)**	− 2.35 (0.42)**		− 2.15 (0.53)**	− 3.30 (0.84)**
Fertilizer (kg/ha)	3.84 (2.93)	4.19 (2.90)		4.59 (3.54)	1.39 (4.85)
Fertilizer squared (/100)	− 0.33 (6.72)	− 0.77 (6.43)		− 2.02 (7.99)	12.60 (12.26)
Seed (kg/ha)	5.86 (1.90)**	5.62 (1.85)**		8.17 (2.24)**	− 0.36 (3.51)
Seed squared (/100)	− 3.12 (2.58)	− 2.95 (2.33)		− 6.92 (3.33)**	2.56 (3.32)
Manure (kg/ha)	0.02 (0.03)	0.03 (0.03)		− 0.01 (0.03)	0.13 (0.08)*
Manure squared (/100)	− 0.00 (0.00)	− 0.00 (0.00)		0.00 (0.00)	− 0.00 (0.00)
Value of equipment (FCFA/10,000)	− 2.08 (2.17)	− 3.75 (2.48)	0.04 (0.02)**	− 3.55 (3.55)	− 0.76 (3.70)
Cattleholdings (number)	5.69 (7.82)	3.98 (8.59)	− 0.05 (0.06)	10.94 (9.58)	− 4.27 (14.36)
Sex of the household head (1 = male)	32.28 (23.93)	43.27 (26.97)*	0.23 (0.19)	12.08 (27.30)	103.96 (54.53)*
Literacy of household head (1 = yes)	46.31 (23.04)**	46.28 (25.42)*	− 0.14 (0.18)	27.30 (27.69)	15.80 (35.21)
Schooling of most educated adult (years)	− 3.23 (3.00)	− 3.10 (3.11)	0.04 (0.02)*	− 0.25 (3.27)	− 0.55 (7.32)
Koranic schooling of adult	− 56.58 (21.66)**	− 40.61 (26.13)	0.88 (0.17)**	− 57.80 (53.24)	− 87.11 (70.28)
Experience of adults (years)	0.08 (0.88)	0.50 (0.87)	0.01 (0.01)*	0.75 (1.24)	1.71 (1.94)
Empowerment[a]	180.46 (50.27)**	394.95 (230.84)*	0.79 (0.45)*	197.65 (70.69)**	− 20.96 (109.46)
Perceives increased drought			0.35 (0.18)*		
High participation in migration (lagged)			0.58 (0.15)**		
Distance to minibus stop			0.04 (0.01)**		
σ_i				183.82 (1.95)**	154.39 (19.55)**
ρ_i				0.05 (0.77)	− 0.30 (0.60)
R^2	0.29	0.26			

Robust standard errors in parentheses; community fixed effects not reported; FCFA 225 = US$1 (purchasing power parity for 2015) (World Bank 2016)

**Significant at the 5% level; *significant at the 10% level

[a] Predicted from first stage regression (see Appendix for estimation results)

Results

Impact of zaï pits on cereal yields

Impact	Decision stage: To adopt	Decision stage: Not to adopt	Treatment effects
Farm households that adopted	(a) 385.11 (14.42)	(c) 338.44 (10.19)	46.67 (11.01)***
Farm households that did not adopt	(d) 435.14 (8.29)	(b) 325.26 (5.73)	109.88 (6.07)***
Heterogeneity effects	− 50.03 (6.08)***	13.18 (2.72)***	− 63.21 (6.70)***

Standard errors in parentheses

***Significance at the 1% level

- In the counterfactual case (c), farm households who adopted would have produced almost 47 kg per hectare less (about 14%) less if they had not adopted.
- In the counterfactual case (d) that farm households that did not adopt adopted, they would have produced about 110 kg (or about 34%) more.
- Last row adjusts for the potential heterogeneity in the sample, shows that farm households who adopted would have produced significantly more than farm households that did not adopt in the counterfactual case

Results

Adoption drivers

- If the household perceives that the drought frequency has increased over the 5 years preceding the survey, it is more likely to have put in place zaï pits.
- Confirms that perceptions of climatic impacts are a driver of adaptation.
- Human capital variables—formal and koranic school education, experience, and predicted empowerment—are also positively associated with adaptation

Productive implications of adoption

- Significant and positive returns to zaï pits.

Heterogeneity

- Households that did not adopt, experience decreasing returns to the seeding rate.
- Returns to empowerment are positive and significant only for households that did not adopt.

Policy implications

1) The perception of climatic change is a driver of adaptation: agricultural adaptation in the face of climate change can be expected to occur autonomously to some extent
2) Empowerment positively affects adaptation behavior: an expansion in the ability to make strategic life choices will contribute to adaptation to climate change.
3) Adaptation to climate change by putting in place zaï pits significantly increases cereal productivity and thereby household incomes and welfare
4) Farm households belonging to the group of adapters have some characteristics (e.g. unobserved skills) that would make them more food secure even without the implementation of the adaptation strategies.