Controlled grazing as a pathway for enhancing investment in multipurpose trees and welfare

Supplementary material

# Section 1: description of study districts and villages

The four districts selected from the Tigray Regional State in northern Ethiopia (see figure 1) are Hinato-Wajerat, Saesi-Tsaeda-Emba, Degua-Tembien and Werileke, which have various climatic and topographic characteristics. These districts are mainly midland and highland areas with altitude ranging from 771 to 3546 m.a.s.l. Rainfall pattern in the districts is erratic and mainly occurs between June and September, with average annual rainfall of 487.4, 543.5, 696.5 and 853.6 mm in Hinato-Wajerat, Saesi-Tsaeda-Emba, Degua-Tembien and Werileke, respectively. The average temperature ranges between 16 and 27°C (Yaebiyo et al., 2021). From these districts, the following 11 villages (Hadush-Hiwot, Gula-Abenae, Saz and Sinkata Freweyni from Saesi-Tsaeda-Emba; Zongi, Edagahamus and Maekelawi from Werileke; Limeat and Aynbrkekin from Degua-Tembien; and Mesanu and Fkre-Alem from Hintalo-Wajerat) were selected.



Figure A.1: Diversity of tree species among adopters and non-adopters of controlled grazing

Table A.1: Operational definition of variables

|  |  |
| --- | --- |
| Variables  | Operational definition |
| *Policy variables* |  |
| Adoption of controlled grazing | 1=adopted controlled grazing; 0=otherwise |
| Plantation of multipurpose trees | 1=planted multipurpose trees; 0 otherwise |
| Species diversity  | Number of multipurpose trees |
| *Demographic variables*  |  |
| Age of household head | Years  |
| Gender of household head | 1=male head; 0=female head |
| Education of household head | Years of schooling  |
| Family size of household | Total number of members |
| Active household members | Number of members between the age of 18 and 65 |
| *Wealth indicators* |  |
| Farmland size | Hectares  |
| Livestock ownership  | Total livestock size in Tropical Livestock Unit  |
| Poor wealth status  | 1=yes; 0=otherwise |
| Medium wealth status | 1=yes; 0=otherwise |
| High-wealth status | 1=yes; 0=otherwise |
| Ownership of improved livestock breed  | 1=yes; 0=otherwise |
| *Access to services* |  |
| Distance to all-weather road | Kilometers |
| Distance to dry-weather road | Kilometers |
| Distance to market | Kilometers  |
| Distance to livestock watering points | Kilometers |
| Irrigation use | 1=yes; 0=otherwise  |
| Improved livestock training  | 1=yes; 0=otherwise |
| Improved agroforestry training  | 1=yes; 0=otherwise |
| Access to agricultural extension  | 1=yes; 0=otherwise |
| *Other characteristics*  |  |
| Membership in community groups | 1=yes; 0=otherwise |
| Feed shortage  | 1=yes; 0=otherwise |
| Strength of grazing bylaws | 1=yes; 0=otherwise |
| Off-farm participation | 1=yes; 0=otherwise |

Table A.2: Summary statistics of variables

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variablesa  | Pooled sample | Non-controlled grazing sample | Controlled grazing sample | Differenceb |
| *Outcome variables* |  |  |  |  |
| Adoption of controlled grazing | 0.58 (0.49) | – | – | – |
| Plantation of multipurpose trees | 0.76 (0.43) | 0.69 (0.46) | 0.80 (0.40) | 7.68\*\*\* |
| Number of trees  | 80 (129) | 53 (67) | 100 (158) | 2.90\*\*\* |
| Income from multipurpose trees  | 851 (762) | 472 (365) | 1121 (907) | 3.20\*\*\* |
| *Demographic variables*  |  |  |  |  |
| Age of household head | 57.3 (13.7) | 57.8 (13.7) | 56.9 (13.8) | 0.72 |
| Gender of household head | 0.90 (0.36) | 0.95 (0.22) | 0.87 (0.43) | 12.1\*\*\* |
| Education of household head | 1.86 (2.82) | 1.55 (2.60) | 2.09 (2.95) | 2.04\*\* |
| Family size of household | 5.32 (1.88) | 5.49 (1.85) | 5.19 (1.90) | 1.70\* |
| Active household members | 3.32 (1.67) | 3.37 (1.32) | 3.29 (1.88) | 0.46 |
| *Wealth indicators* |  |  |  |  |
| Farmland size | 0.79 (0.53) | 0.86 (0.73) | 0.73 (0.32) | 2.57\*\* |
| Livestock ownership  | 3.70 (2.25) | 4.32 (2.13) | 3.27 (2.23) | 5.15\*\*\* |
| Poor wealth status  | 0.09 (0.28) | 0.06 (0.23) | 0.11 (0.32) | 4.50\*\*\* |
| Medium wealth status | 0.69 (0.46) | 0.71 (0.46) | 0.67 (0.47) | 0.62 |
| High-wealth status | 0.23 (0.42) | 0.24 (0.43) | 0.22 (0.41) | 0.32 |
| Ownership of improved livestock breed  | 0.15 (0.36) | 0.14 (0.35) | 0.16 (0.37) | 0.25 |
| *Access to services* |  |  |  |  |
| Distance to all-weather road | 1.17 (1.74) | 1.51 (2.19) | 0.93 (1.28) | 3.67\*\*\* |
| Distance to dry-weather road | 0.65 (0.96) | 0.75 (1.25) | 0.58 (0.67) | 1.99\*\* |
| Distance to market | 5.63 (4.09) | 5.81 (4.15) | 5.51 (4.06) | 0.79 |
| Distance to livestock watering points | 1.22 (1.21) | 1.40 (1.29) | 1.09 (1.13) | 2.80\*\* |
| Irrigation use | 0.28 (0.45) | 0.21 (0.41) | 0.34 (0.47) | 9.24\*\*\* |
| Improved livestock training  | 0.16 (0.36) | 0.09 (0.28) | 0.21 (0.40) | 12.8\*\*\* |
| Improved agroforestry training  | 0.33 (0.47) | 0.22 (0.42) | 0.40 (0.49) | 17.1\*\*\* |
| Access to agricultural extension  | 0.52 (0.50) | 0.49 (0.50) | 0.55 (0.50) | 1.54 |
| *Other characteristics*  |  |  |  |  |
| Membership in community groups | 0.21 (0.41) | 0.17 (0.38) | 0.24 (0.43) | 3.30\* |
| Feed shortage  | 0.62 (0.49) | 0.68 (0.47) | 0.57 (0.50) | 4.98\*\* |
| Strength of grazing bylaws | 0.26 (0.44) | 0.19 (0.40) | 0.30 (0.46) | 6.90\*\*\* |
| Off-farm participation | 0.30 (0.46) | 0.24 (0.43) | 0.35 (0.48) | 6.78\*\*\* |

a Table A.1 in the appendix presents the operational definition of variables.

b Difference is computed using t-test for continuous variables and Pearson Chi-squared test for categorical variables.

\**p*<0.1, \*\* *p*<0.05, and \*\*\* *p*<0.01.

Source: own data.

Table A.3: Falsification test for instruments

|  |  |  |  |
| --- | --- | --- | --- |
|  | Controlled grazing | Tree plantation | Income from trees |
| Pasture availability | 0.713 (0.208)\*\*\* | 0.196 (0.161) | 88.4 (288.5) |
| Control variables  | Yes  | Yes  | Yes  |
| District fixed effects | Yes  | Yes  | yes |

Note: values in parentheses are standard errors.

\*\*\* *p*<0.01.

Source: own estimates.

Table A.4: Parsimonious and full model for plantation of MPTs

|  |  |  |
| --- | --- | --- |
|  | 2–SCML (plantation) | IV–Poisson (number of trees) |
| Controlled grazing | 9.965\*\*\* (2.024) | 11.10\*\*\* (2.247) | 4.365 (6.692) | 2.076\*\*\* (0.571) |
| Generalized residual |  | 6.241\*\*\* (1.275) |  |  |
| Gender |  | 0.300\*\* (0.154) |  | 0.195 (0.238) |
| Age  |  | –0.040 (0.058) |  | –0.035 (0.039) |
| Education  |  | –0.062\*\* (0.028) |  | –0.073\*\* (0.037) |
| Household size  |  | 0.131\*\*\* (0.031) |  | –0.025 (0.039) |
| Medium wealth |  | 0.451\*\* (0.221) |  | 0.604\*\* (0.285) |
| High wealth |  | 0.758\*\* (0.306) |  | 0.871\*\*\* (0.303) |
| Access to extension |  | 0.366\*\*\* (0.120) |  | 0.376\*\*\* (0.143) |
| Off-farm participation |  | –0.391\*\*\* (0.146) |  | –0.200 (0.203) |
| Land size  |  | 0.235\*\* (0.091) |  | 0.087 (0.139) |
| Livestock size |  | 0.270\*\*\* (0.076) |  | 0.122\*\* (0.049) |
| Feed shortage |  | 0.657\*\*\* (0.140) |  | –0.015 (0.136) |
| Distance to all-weather road |  | 0.186\*\*\* (0.043) |  | 0.080 (0.052) |
| Distance to dry-weather road |  | –0.083 (0.078) |  | 0.039 (0.105) |
| Distance to market |  | 0.030 (0.020) |  | 0.002 (0.016) |
| Distance to livestock water points |  | 0.117\* (0.062) |  | 0.086 (0.073) |
| Distance to water source for humans |  | 0.263\*\* (0.104) |  | 0.161 (0.116) |
| Constant  | –0.134(0.138) | –9.319\*\*\* (1.471) | –0.642\*\*\* (0.192) | –1.058 (0.989) |
| Fixed effects | Yes | Yes |  | Yes |
| Observations | 474 | 474 |  | 474 |

 Robust standard errors are reported in parentheses. For the 2–SCML, bootstrapped standard errors are reported. \**p*<0.1, \*\* *p*<0.05 and \*\*\* *p*<0.01. Source: own estimates.

Table A.5: OLS estimates of the effect of controlled grazing on trees investment and income

|  |  |  |  |
| --- | --- | --- | --- |
|  | Plantation | Number of trees | Income |
| Controlled grazing | 0.262\*\*\* (0.057) | 0.784\*\*\* (0.171) | 589.6\*\*\* (191.7) |
| Gender | –0.016(0.044) | –0.031(0.231) | 521.7\*\* (212.4) |
| Age  | 0.004(0.013) | 0.051(0.052) | 48.87 (56.84) |
| Education  | 0.009(0.006) | 0.024(0.024) | 1.568(4.527) |
| Household size  | 0.037\*\*\* (0.008) | –0.030(0.034) | –33.49(85.43) |
| Medium wealth | 0.147\*(0.082) | 0.740\*\*\*(0.214) | 440.1\* (262) |
| High wealth | 0.228\*\* (0.088) | 1.269\*\*\* (0.309) | 860.1\*\* (380.2) |
| Access to extension | 0.179\*\*\* (0.037) | 0.446\*\* (0.169) | –171.5(228.8) |
| Off-farm participation | –0.046(0.054) | 0.283(0.177) | –59.12(213.9) |
| Land size  | 0.027(0.032) | 0.047(0.119) | 312.5\*\* (159.2) |
| Livestock size | 0.029\*(0.014) | 0.081\*\*(0.036) | 32.07(62.07) |
| Feed shortage | 0.142\*\*\* (0.042) | 0.027(0.184) | –404.1\*\*(235) |
| Distance to all-weather road | 0.012\*\*\* (0.012) | –0.056\*\*\* (0.025) | –72.93\*\* (34.02) |
| Distance to dry-weather road | –0.029(0.023) | 0.067(0.076) | 54.51(80.33) |
| Distance to market | 0.007(0.006) | –0.005(0.032) | 12.40(25.55) |
| Distance to livestock watering points | –0.006 (0.016) | 0.009(0.048) | –141.3\*\*\* (64.42) |
| Distance to water source for humans | 0.066\* (0.033) | –0.079 (0.126) |  |
| Constant  | –0.258(0.332) | –1.703(1.429) | –1408(1450) |
| Fixed effects | Yes | Yes | Yes |
| Observations | 474 | 474 | 474 |

 Robust standard errors are reported in parentheses.

 \**p*<0.1, \*\* *p*<0.05 and \*\*\* *p*<0.01.

 Source: own estimates.References

Yaebiyo, G., E. Birhane, T. Tadesse, S. Kiros and K.M. Hadgu. “Evaluating woody species composition and regeneration in controlled and free grazing systems for scaling up agroforestry in the highlands of northern Ethiopia.” Agroforestry Systems 95 (2021): 1229–1244.

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