‘Supplementary Information: This Supplementary Information has not been peer reviewed. Title: Climate-mediated upward shift of coffee agroforestry and associated reforestation in Arabica coffee’s native range’

Table S1. Statistical overview comparing the reasons for the establishment of coffee agroforestry between farmers who established coffee agroforests within existing forests versus on open land. Shown are the number of respondents who cited and did not cite each reason, as well as the proportion of farmers who cited the reason, separately for each agroforestry type, as well as the P-values from Fisher's exact tests. Reasons that differed significantly ($P < 0.05$) between farmers who established agroforestry on open land versus within existing forests are indicated in bold. Note that there were a total of 8 forest-derived plots, and 22 open-land-derived plots.

	Forest-derived			**Open-land-derived**			
Reasons	**Cited**	**Not cited**	**Percentage**	**Cited**	**Not cited**	**Percentage**	**P-value**
Climate change	8	0	100	22	0	100	1.00
Rise in temperature	6	2	75	22	0	100	0.06
Decrease in rainfall	1	7	13	0	22	0	0.27
Both rise in temperature and decrease in rainfall	1	7	13	0	22	0	0.27
Desire for better income	7	1	88	9	13	41	**0.04**
Following others	3	5	38	6	16	27	0.67
Crop raiding	0	8	0	8	14	36	0.07
Decline in yield of other crops	0	8	0	7	15	32	0.14
Land unsuitable for other purposes	2	6	25	1	21	5	0.16
District-mandated	0	8	0	1	21	5	1.00
Resettlement	0	8	0	1	21	5	1.00
Increased coffee prices	0	8	0	1	21	5	1.00
Desire to get coffee for own consumption	0	8	0	1	21	5	1.00

Table S2. Statistical overview comparing the advantages and disadvantages of the establishment of coffee agroforests between farmers who established coffee agroforests within existing forests versus on open land. Shown are the number of respondents who cited and did not cite each reason, as well as the proportion of farmers who cited the reason, separately for each agroforestry type, as well as the P-values from Fisher's exact tests. Reasons that differed significantly ($P < 0.05$) between farmers who established agroforestry on open land versus within existing forests are indicated in bold. Note that there were a total of 8 forest-derived plots, and 22 open-land-derived plots.

	Forest-derived			**Open-land-derived**			
Advantages/ Disadvantages	**Cited**	**Not cited**	**Percentage**	**Cited**	**Not cited**	**Percentage**	**P-value**
Better income	8	0	100	22	0	100	1.00
Coffee for own consumption	6	2	75	17	5	77	1.00
Wood for fuel and construction	0	8	0	16	6	73	**<0.001**
Shade from the sun	0	8	0	14	8	64	**0.003**
Fruit from shade trees	0	8	0	2	20	9	1.00
High initial investment costs	6	2	75	16	6	73	1.00
No disadvantages	2	6	25	6	16	27	1.00

Table S3. Statistical overview of the effect of agroforestry type, elevation and time since establishment on species richness, diversity, abundance and community composition of adult woody plants and saplings for thirty agroforests in southwestern Ethiopia. Shown are test statistics (X^2 or F-value), degrees of freedom (DF) and P-values from univariate (species richness, Shannon diversity, abundance and median DBH) and multivariate models (community composition). P-values in bold are significant at P<0.05.

		Agroforestry type			**Elevation**			**Time since establishment**		
Community descriptor	**Tree size**	**X^2 / F-value**	**DF**	**P-value**	**F-value**	**DF**	**P-value**	**F-value**	**DF**	**P-value**
Species richness	Adult woody plants	0.61	1, 28	0.44	0.63	1, 28	0.43	0.04	1, 28	0.84
Diversity	Adult woody plants	0.03	1, 28	0.86	1.65	1, 28	0.21	0.12	1, 28	0.73
Abundance	Adult woody plants	4.09	1, 28	0.053	0.96	1, 28	0.33	0.001	1, 28	0.97
Median DBH	Adult woody plants	9.66	1	**0.002**	0.85	1, 28	0.36	4.26	1, 28	**0.048**
Community composition	Adult woody plants	1.91	1, 28	**0.03**	0.67	1, 28	0.8	1.15	1, 28	0.31
Species richness	Saplings	2.64	1, 28	0.12	0.38	1, 28	0.54	1.55	1, 28	0.22
Diversity	Saplings	2.46	1, 28	0.13	0.02	1, 28	0.88	1.51	1, 28	0.23
Abundance	Saplings	1.69	1, 28	0.21	1.47	1, 28	0.24	0.86	1, 28	0.36
Community composition	Saplings	1.14	1, 17	0.25	0.63	1, 17	0.87	0.93	1, 17	0.52

Table S4. Frequency of occurrence of adult woody plants and sapling in eight forest-derived and twenty-two open-land-derived agroforests in south-western Ethiopia. Shown are the scientific species name, and the number of sites where adult individuals (and saplings) were present, separately for forest- and open-land-derived agroforests.

Species	**Family**	**Origin**	**Frequency of occurrence in forest-derived**	**Frequency of occurrence in open-land-derived**
Acacia abyssinica	Fabaceae	Indigenous	0(0)	3(0)
Albizia gummifera	Fabaceae	Indigenous	3(0)	7(6)
Albizia schimperiana	Fabaceae	Indigenous	1(1)	5(0)
Allophylus abyssinicus	Sapindaceae	Indigenous	1(0)	0(1)
Apodytes dimidiata	Icacinaceae	Indigenous	0(0)	1(0)
Bersama abyssinica	Melianthaceae	Indigenous	3(0)	2(1)
Brucea antidysenterica	Simaroubaceae	Indigenous	0(0)	1(0)
Clausena anisata	Rutaceae	Indigenous	0(1)	0(0)
Cordia africana	Boraginaceae	Indigenous	0(0)	5(1)
Croton macrostachyus	Euphorbiaceae	Indigenous	7(2)	15(5)
Cupressus lusitanica	Cupressaceae	Exotic	0(0)	1(0)
Ehretia cymosa	Boraginaceae	Indigenous	1(1)	1(0)
Ekebergia capensis	Meliaceae	Indigenous	0(1)	2(0)
Erythrina brucei	Fabaceae	Indigenous	0(0)	7(1)
Eucalyptus camaldulensis	Myrtaceae	Exotic	0(0)	3(0)
Ficus sur	Moraceae	Indigenous	4(0)	2(0)
Grevillea robusta	Proteaceae	Exotic	0(0)	1(0)
Macaranga capensis	Euphorbiaceae	Indigenous	1(0)	0(0)
Maesa lanceolata	Myrsinaceae	Indigenous	2(0)	3(3)
Maytenus gracilipes	Celastraceae	Indigenous	0(0)	1(1)
Millettia ferruginea	Fabaceae	Indigenous	4(1)	6(4)
Pentas schimperiana	Rubiaceae	Indigenous	0(0)	1(0)
Persea americana	Lauraceae	Exotic	0(0)	6(2)
Prunus africana	Rosaceae	Indigenous	0(0)	1(1)
Prunus persica	Rosaceae	Exotic	0(0)	1(0)
Psidium guajava	Myrtaceae	Exotic	0(0)	2(0)
Ricinus communis	Euphorbiaceae	Indigenous	0(0)	5(3)
Senna occidentalis	Fabaceae	Exotic	0(0)	1(1)
Sesbania sesban	Fabaceae	Indigenous	0(0)	7(2)
Solanecio gigas	Asteraceae	Indigenous	0(0)	0(1)
Syzygium guineense	Myrtaceae	Indigenous	1(0)	1(1)
Teclea nobilis	Rutaceae	Indigenous	2(0)	1(0)
Vernonia amygdalina	Asteraceae	Indigenous	5(2)	14(9)
Vernonia auriculifera	Asteraceae	Indigenous	4(1)	11(10)

Table S5. Statistical overview of the effect of human intervention in the regeneration process, elevation and time since establishment on species richness, diversity, abundance and community composition of adult woody plants and saplings for eight forest-derived agroforests in southwestern Ethiopia. The regeneration process was represented as a fixed factor with two levels: (i) no human intervention (n = 5 sites) and (ii) trees were planted (n = 3 sites). Shown are test statistics (X^2 or F-value), degrees of freedom (DF) and P-values from univariate (species richness, Shannon diversity, abundance and median DBH) and multivariate models (community composition). P-values in bold are significant at P<0.05.

		Regeneration process			**Elevation**			**Time since establishment**		
Community descriptor	**Tree size**	**X^2/ F-value**	**DF**	**P-value**	**F-value**	**DF**	**P-value**	**F-value**	**DF**	**P-value**
Species richness	Adult woody plants	0.31	1, 6	0.6	1.05	1, 6	0.34	0.44	1, 6	0.53
Diversity	Adult woody plants	0.76	1, 6	0.42	1.7	1, 6	0.24	0.61	1, 6	0.46
Abundance	Adult woody plants	0	1, 6	0.96	0.37	1, 6	0.57	0.16	1, 6	0.7
Median DBH	Adult woody plants	4.41	1	**0.035**	1.89	1, 6	0.22	2.69	1, 6	0.15
Community composition	Adult woody plants	0.02	1, 6	1	0.52	1, 6	0.81	1.61	1, 6	0.18
Species richness	Saplings	21.84	1, 6	**0.003**	0.33	1, 6	0.58	0.37	1, 6	0.56
Diversity	Saplings	5.75	1, 6	0.05	0.25	1, 6	0.64	0.22	1, 6	0.66
Abundance	Saplings	8.77	1, 6	**0.025**	0.18	1, 6	0.67	0.29	1, 6	0.61
Community composition	Saplings									

Table S6. Statistical overview of the effect of human intervention in the regeneration process, elevation and time since establishment on species richness, diversity, abundance and community composition of adult woody plants and saplings for twenty-two open-land-derived agroforests in southwestern Ethiopia. The regeneration process was represented as a fixed factor with three levels: i) trees were planted (n = 8 sites), ii) trees were allowed to regenerate naturally (n = 5 sites), or iii) trees were both planted and allowed to regenerate naturally (n = 9 sites). Shown are test statistics (X^2 or F-value), degrees of freedom (DF) and P-values from univariate (species richness, Shannon diversity, abundance and median DBH) and multivariate models (community composition). P-values in bold are significant at P<0.05.

		Regeneration process			**Elevation**			**Time since establishment**		
Community descriptor	**Tree size**	**X2 /F-value**	**DF**	**P-value**	**F-value**	**DF**	**P-value**	**F-value**	**DF**	**P-value**
Species richness	Adult woody plants	0.2	2, 19	0.82	0.11	1, 20	0.74	1.18	1, 20	0.29
Diversity	Adult woody plants	0.39	2, 19	0.68	0.61	1, 20	0.44	0.72	1, 20	0.41
Abundance	Adult woody plants	2.99	2, 19	0.07	1.27	1, 20	0.27	0.39	1, 20	0.54
Median DBH	Adult woody plants	0.14	2	0.93	0.69	1, 20	0.42	0.67	1, 20	0.42
Community composition	Adult woody plants	1.13	2, 19	0.28	0.8	1, 20	0.67	1.41	1, 20	0.14
Species richness	Saplings	1.22	2, 19	0.32	0.26	1, 20	0.62	2.77	1, 20	0.11
Diversity	Saplings	0.53	2, 19	0.59	0.01	1, 20	0.92	1.68	1, 20	0.21
Abundance	Saplings	0.64	2, 19	0.54	1.41	1, 20	0.25	1.2	1, 20	0.29
Community composition	Saplings	0.87	2, 13	0.64	0.98	1, 14	0.49	0.97	1, 14	0.54

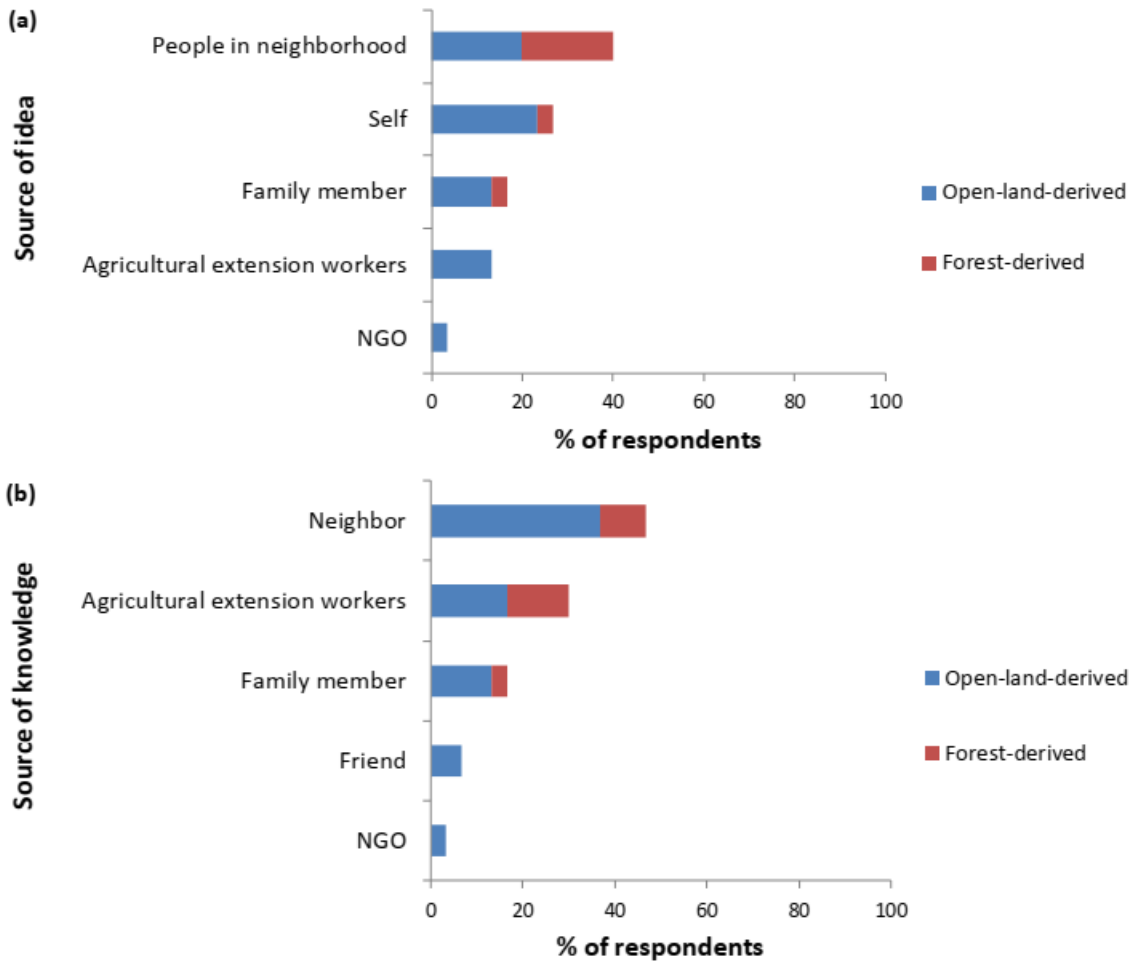

Figure S1. The source of **(a)** ideas and **(b)** knowledge of planting coffee in the novel range in thirty sites in southwestern Ethiopia. The legend indicates whether farmers established open-land or forest-derived agroforests.

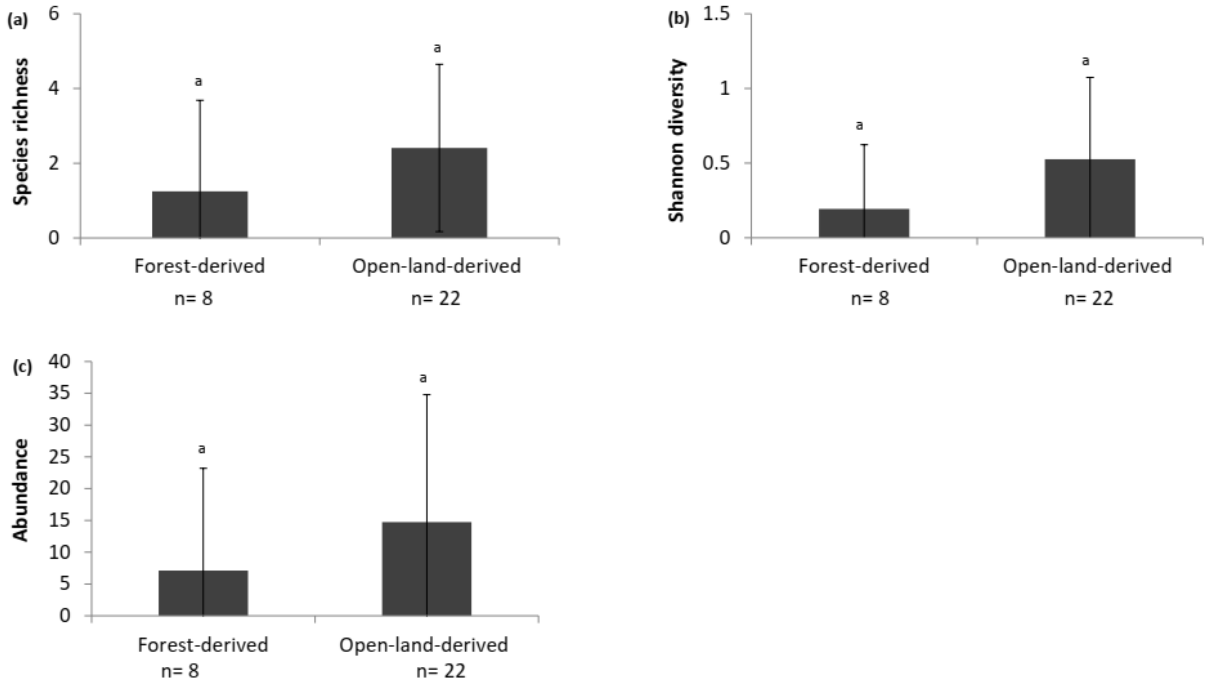

Figure S2. The characteristics of the woody plant saplings in eight forest-derived and twenty-two open-land-derived agroforests in southwestern Ethiopia. Shown are (a) species richness, (b) Shannon diversity and (c) median DBH of saplings. Error bars represent standard deviations. Significant differences between forest-derived and open-land-derived agroforests are indicated by a letter above the vertical bars, where groups with the same letter do not differ.

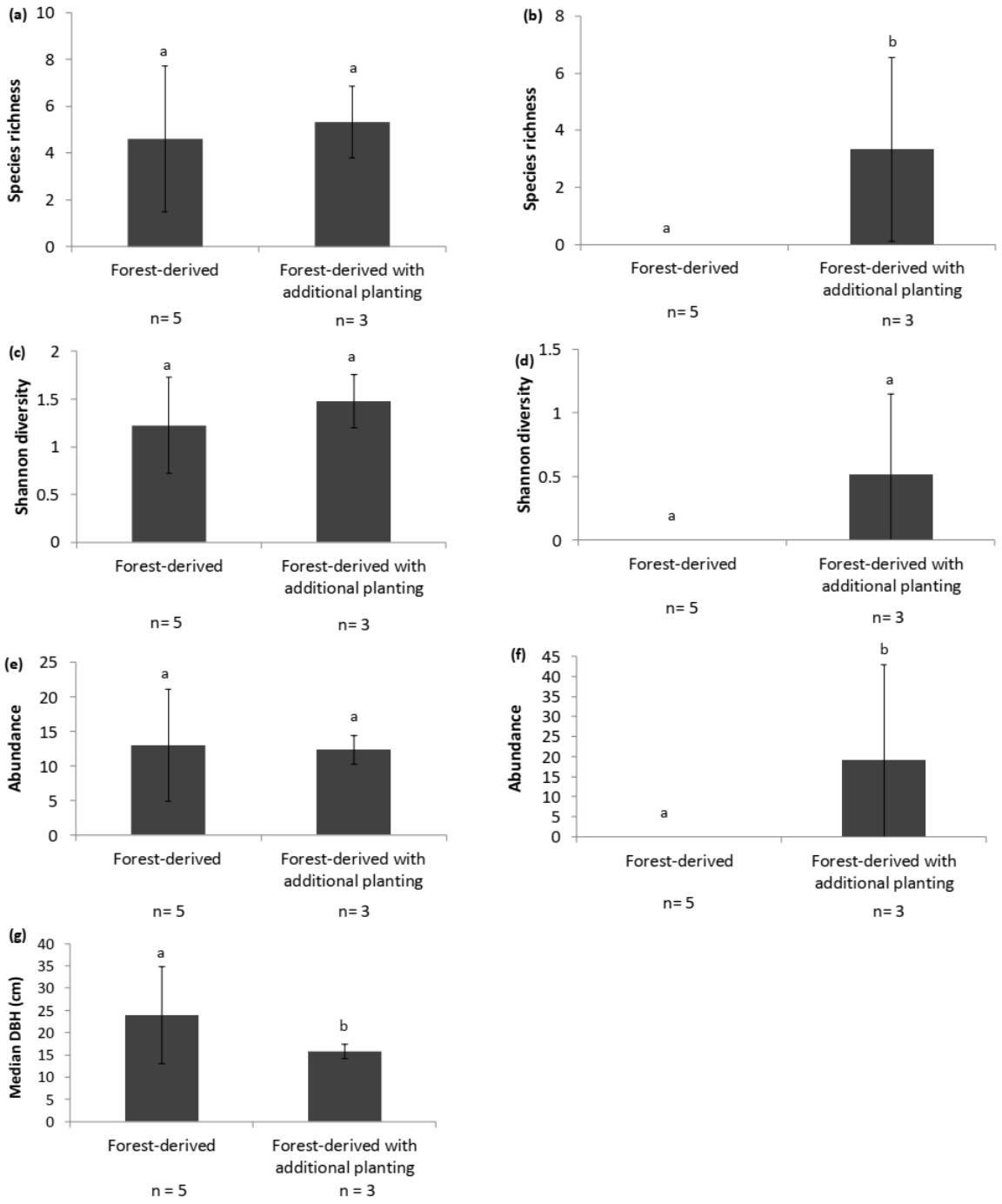

Figure S3. The effect of human intervention in the regeneration process for the woody plant community in five forest-derived agroforests without additional planting and three forest-derived agroforests with additional planting in southwestern Ethiopia. Shown are **(a, b)** species richness**, (c, d)** Shannon diversity, **(e, f)** abundance, and **(g)** median DBH (diameter at breast height) of adult woody plants (left column) and saplings (right column). Error bars represent standard deviations. Significant differences between forest-derived agroforests with and without additional planting are indicated by a letter above the vertical bars, where groups with the same letter do not differ.

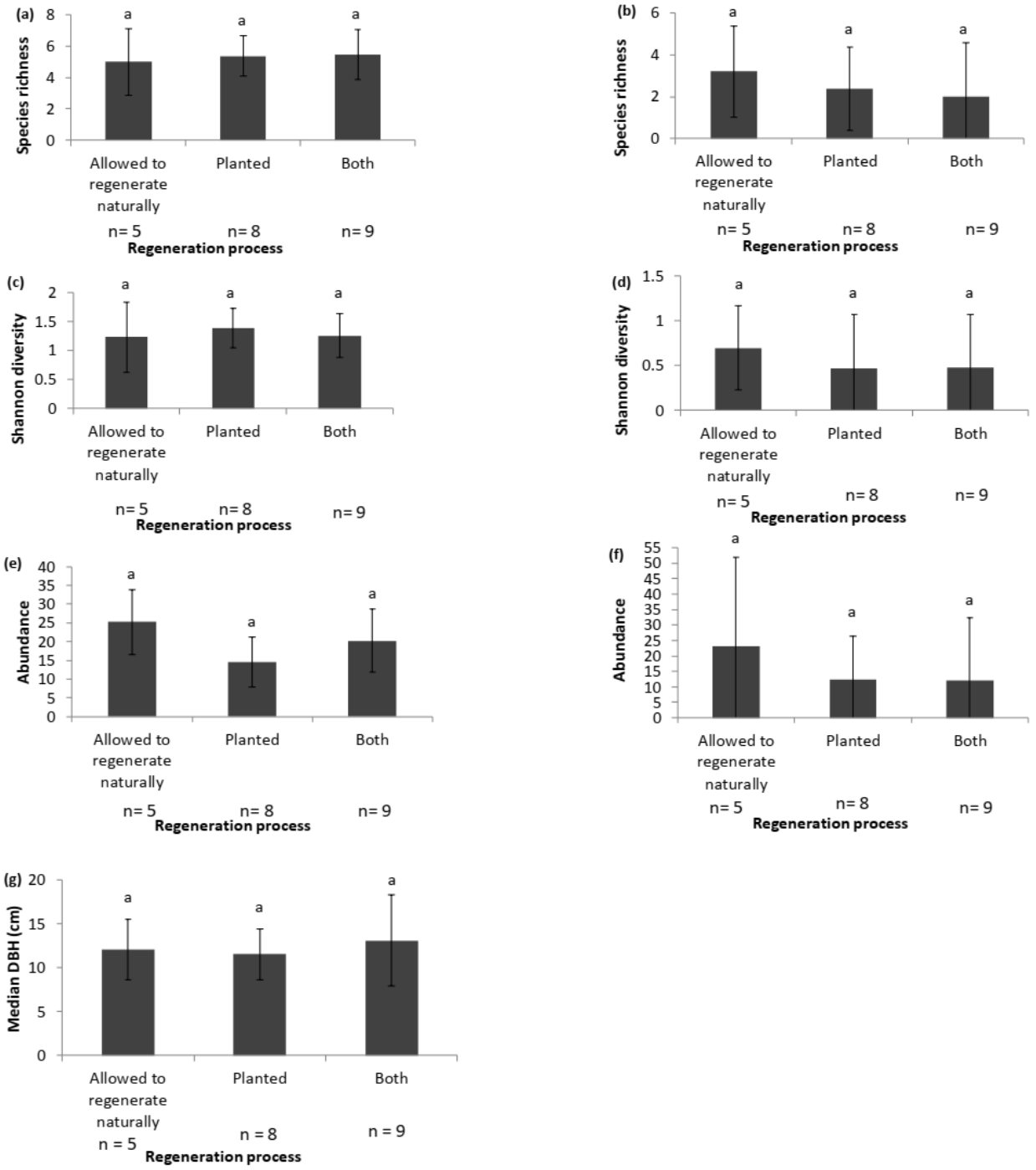

Figure S4. The effect of human intervention in the regeneration process for the woody plant community in 22 open-land-derived agroforests where trees were allowed to regenerate naturally, were planted, or were both allowed to regenerate naturally and planted in southwestern Ethiopia. Shown are **(a, b)** species richness**, (c, d)** Shannon diversity, **(e, f)** abundance, and **(g)** median DBH (diameter at breast height) of adult woody plants (left column) and saplings (right column). Error bars represent standard deviations. Significant differences between open-land-derived agroforests where trees were allowed to regenerate naturally, were planted, or were both allowed to regenerate naturally and planted are indicated by a letter above the vertical bars, where groups with the same letter do not differ.

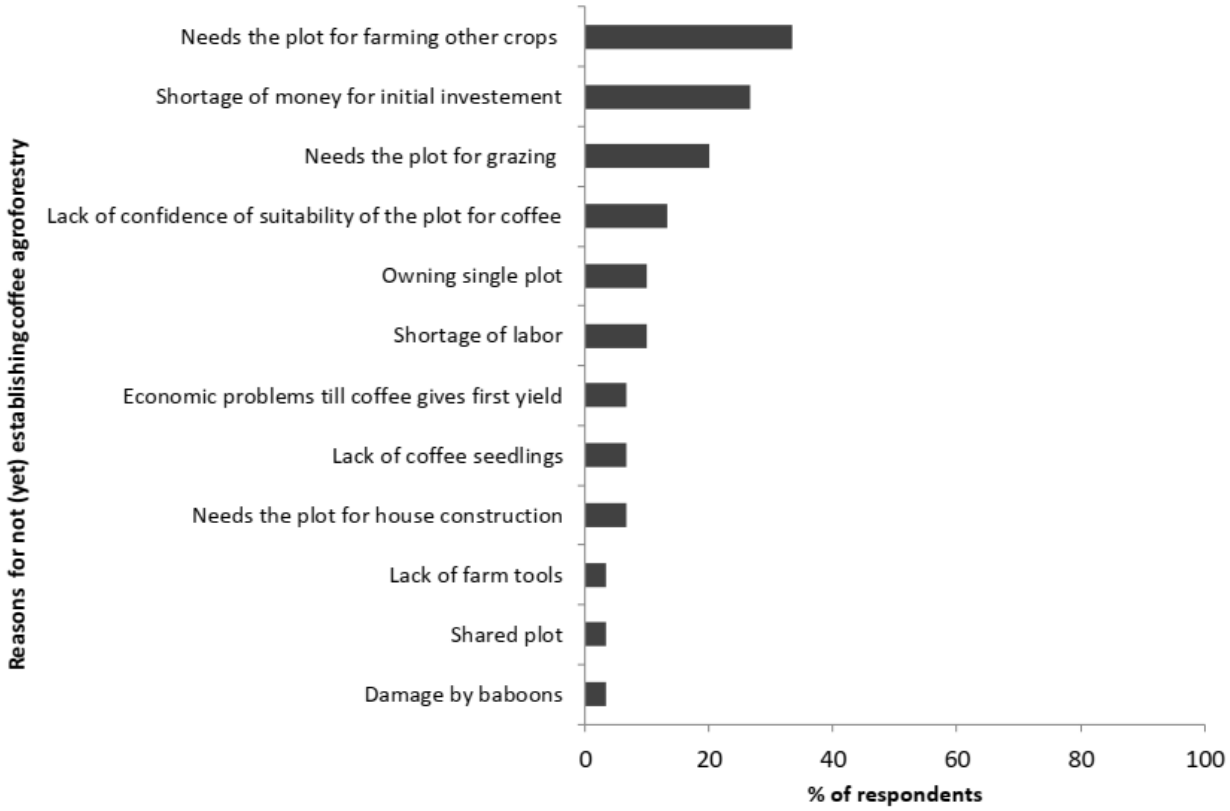

Figure S5. The reasons for not (yet) starting coffee agroforests in the novel range of thirty farmers in the novel range in southwestern Ethiopia.

Appendices

General directions

Dear participants, the following questionnaire is a part of the research conducted under the supervision of Addis Ababa University. The main aims of the project are to study the reasons for establishing and not (yet) establishing coffee agroforestry in the novel range. Also, we hope to understand the advantages and disadvantages of establishing coffee agroforestry as well as the expected advantages and limitation of establishing coffee agroforestry in future in the novel range. We guarantee you that all information submitted will be treated with the utmost confidentiality and only for research purposes.

Thank you for your contribution.

Date----------

General information of the land owner or user

Respondent Number (site number in which the interview is conducted) ----------

Latitude ---------- Longitude----------

Age----------

Gender: Male ☐ Female ☐

Place----------

Name of the interviewer----------

Appendix A

Questionnaire to smallholder farmers who established coffee agroforestry in the novel range

This questionnaire will only be administered to those smallholder farmers in the novel range who already switched to coffee production

1. When did you start growing coffee on your farm?----------

What did you grow here before you started growing coffee on your farm? Or what was the land use on this plot before you started growing coffee? ----------

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2. Why did you start to grow coffee in the novel range? What were the reason(s) for establishing coffee agroforestry in the novel range?----------

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3. Did you plant your own shade trees? Or did you allow shade trees to regenerate naturally?---

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Or did you start growing coffee in an existing forest patch or inside the existing forest? If so, did you do additional planting of shade trees?

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4. What are the benefits or advantages you have received by growing coffee in the novel range? ----------

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What are the disadvantages you faced by growing coffee in the novel range?----------

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5. From what persons or institutions did you get the idea to start growing coffee?----------

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From what persons or institutions did you get the knowledge on coffee production?

Appendix B

Questionnaire to smallholder farmers who did not (yet) establish coffee agroforestry in the novel range

This questionnaire will only be administered to neighboring farmers who did not (yet) switch to coffee production

1. What is the current land use of your plot? (Also we will observe it since we will conduct the interview on the plot)

---

2. We observed that one of your neighbors has started growing coffee. Are there any particular reasons for why you did not start growing coffee (yet)?----------

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3. Do you plan to start growing coffee here in the novel range in the future? ----------

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If you plan to establish coffee in the novel range in the future, would you do this inside the forest (forest-derived) or on open land (open-land-derived)? ----------

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If you have a plan to start growing coffee or establishing coffee at the novel range in the future, what are the advantages that you expect from this action? What will be the challenges and limitations?

Expected advantages ----------

Expected challenges and limitations----------

Thank you for your time and sharing your invaluable knowledge!