Projections of local knowledge-based adaptation strategies of Mexican coffee farmers

Supplementary material

Supplementary Material 1. Calculation and variables used by CO2Fix model

The stem growth and biomass were expressed as a function of the current annual increase (CAI). The CAI of each cohort was calculated based on the actual above-ground biomass over the current achievable maximum of the cohort (Table SM1 and SM2). The aerial biomass and the CAI of the shadow trees (banana treen, coffee, living barriers and living fences) were determined using the database generated from an inventory previously carried out by Ruiz et al. (2020) in 25 coffee plots. Wood density for shadow trees, living barriers and living fences was obtained from Díaz et al. (2015); for banana and coffee cohorts from Negash and Kanninen (2015). The percentage of carbon content was taken from Kuyah et al. (2012) while, for banana and coffee cohort it was taken from Negash, Starr, and Kanninen (2013) and Negash, Starr, Kanninen, et al. (2013) respectively. The growth of foliage, branches and roots with respect to stem growth was calculated with allometric equations for dominant tree species (Segura, Kanninen and Suárez, 2006); for coffee plants we follow Negash et al., (2013) and for banana tree Nyombi et al. (2009). The coefficient of rotation of foliage, branches and roots for all cohorts was obtained from Negash and Kanninen (2015). Natural and harvested mortality for all cohorts were from field observations (Table SM1 and SM2).

Table SM1. Input data to run CO2Fix model in the biomass module. Example of a plot with base scenario 1 (Shade trees-coffee-living barriers).

Cohort	Maximum aboveground biomass (Mg ha^{-1})	C content (%)	Wood density (MgDM/m3)	Bio/ Biomax	Stem		Foliage		Branch		Roots		
					Growth (ICA m^3 ha^{-1})	Initial C (Mg ha^{-1})	Relative growth	Initial C (Mg ha^{-1})	Relative growth	Initial C (Mg/ha)	Relative growth	Initial C (Mg/ha)	Mortality (20% ST*; 10% coffee)
				0.000	0.000		0.000		0.000		0.000		0.050
				0.016	9.108		0.079		0.175		0.101		0.020
				0.042	13.790		0.180		0.597		0.265		0.020
Shade trees	36.5	0.48	0.6	0.131	28.242	8.716	0.446	1.741	1.664	6.025	0.814	2.979	0.020
				0.156	16.428		0.519		1.976		0.970		0.020
				0.272	13.266		0.838		3.409		1.690		0.020
				0.500	3.000		0.800		3.000		1.000		0.050
				0.002	0.670		0.001		0.011		0.005		0.030
				0.009	3.856		0.006		0.066		0.029		0.010
Coffee	13.99	0.49	0.62	0.025	0.528	3.791	0.016	0.319	0.136	2.649	0.058	1.141	0.010
				0.057	0.100		0.038		0.317		0.137		0.040
				0.000	0.000		0.000		0.000		0.000		0.050
				0.001	0.910		0.007		0.017		0.010		0.020
				0.004	1.379		0.018		0.059		0.026		0.020
Live barriers	3.65	0.48	0.6	0.013	2.824	1.752	0.044	0.174	0.166	0.602	0.081	0.297	0.020
				0.015	1.642		0.051		0.197		0.097		0.020
				0.027	1.326		0.083		0.340		0.169		0.020
				0.050	0.300		0.080		0.300		0.100		0.050

ST* = Shade tres. For all cohorts: Foliage rotation rate: stem and foliage, 0.5; branches, 0.05 and roots, 0.05.

Table SM2. Input data to parameterize the CO2Fix model in the biomass module. Example of a plot with base scenario 3 (Shade trees-banana-coffee-living fences).

Cohort	Maximum aboveground biomass (Mg ha-1)	C content (%)	Wood density (MgDM/m3)	Bio/ Biomax	Stem		Foliage		Branch		Roots		Mortality (20% ST; 10% coffee and banana)
					Growth (CAI m^3 ha^{-1})	Initial C (Mg ha^{-1})	Relative growth	Initial C (Mg ha^{-1})	Relative growth	Initial C (Mg ha^{-1})	Relative growth	Initial C (Mg ha^{-1})	
Shade trees	12.866	0.480	0.600	0	0	3.267	0	0.785	0	1.781	0	1.040	0.050
				0.010	0.122		0.018		0.059		0.021		0.020
				0.027	0.463		0.047		0.090		0.060		0.020
				0.055	5.672		0.090		0.184		0.120		0.020
				0.101	10.558		0.172		0.376		0.221		0.020
				0.441	2.651		0.692		1.703		0.964		0.020
				0.800	0.500		0.600		1.700		0.960		0.050
Banana	1.628	0.470	0.200	0	0	0.405	0	0.163			0	0.044	0.030
				0.005	0.128		0.000				0.000		0.010
				0.009	2.854		0.002				0.001		0.010
				0.015	10.616		0.006				0.002		0.010
				0.024	1.715		0.011				0.003		0.010
				0.050	0.500		0.010				0.002		0.030
Coffee	2.369	0.490	0.620	0	0	0.656	0	0.055	0	0.458	0	0.197	0.040
				0.006	0.910		0.001		0.006		0.002		0.030
				0.049	0.220		0.006		0.046		0.020		0.010
				0.050	0.100		0.005		0.040		0.010		0.200
Living fences	3.858	0.480	0.600	0	0	0.978	0	0.235	0	0.534	0	0.312	0.050
				0.003	0.036		0.005		0.017		0.006		0.020
				0.008	0.138		0.014		0.027		0.018		0.020
				0.016	1.701		0.027		0.055		0.036		0.020
				0.030	3.167		0.051		0.112		0.006		0.020
				0.132	0.795		0.207		0.510		0.289		0.020
				0.240	0.150		0.180		0.510		0.288		0.050

C = Carbon; CAI = current annual increment

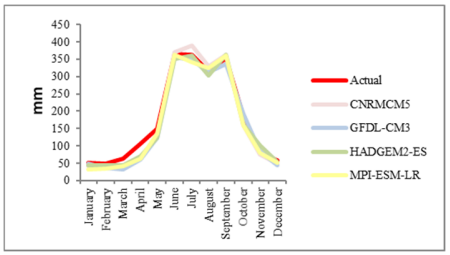
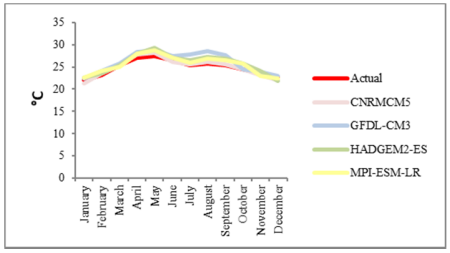
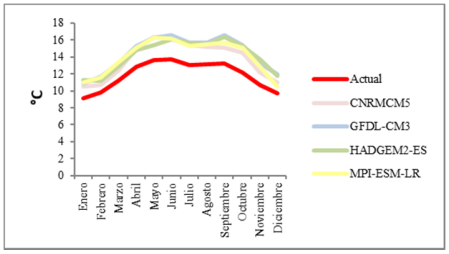
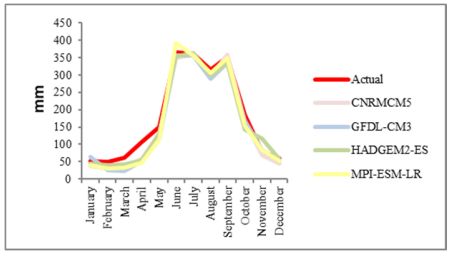
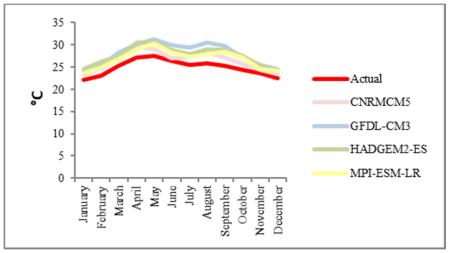
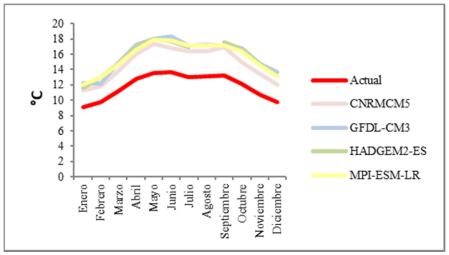
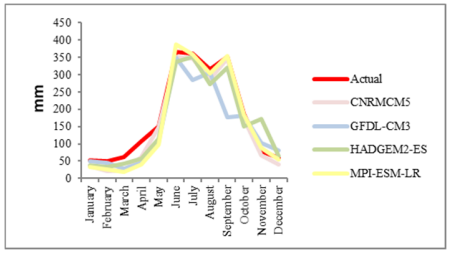
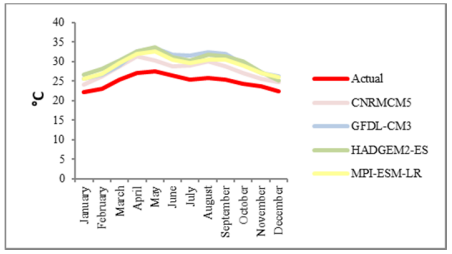
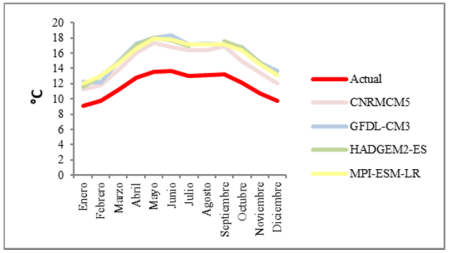
For all cohorts: Foliage rotation rate: stem and foliage, 0.5; branches, 0.05 and roots, 0.05.

Supplementary Material 2. Weather events recorded in media from 1970 to 2013

Municipality	Date	Weather event	Damages
Coscomatepec	17/Nov/1970	Snowfall	Coffee plantations with damages. Losses in plants, grains. Low coffee quality for trade.
Coatepec	25/Nov/1970	Frost	Coffee plantations with damages. Losses in plants, grains. Low coffee quality for trade.
Coatepec	26/Oct/1970	Frost	It affected the coffee harvest, the farmers thought about changing products
Coscomatepec	19/Mar/1976	Hail	Crop losses
Coatepec	3/May/1981	Storm, heavy winds	No Data
Coatepec	10/Jun/1996	Frost	Crops damages
Coatepec	11/Apr/1999	Forest fire	No Data
Coscomatepec	02/May/2006	Hail	Effects on agriculture and livestock
Coscomatepec	12/Dec/2006	Frost	Municipality declared in emergency. Impact on agriculture and livestock.
Coscomatepec	09/Jun/2008	Landslides	Damage to highways and roads
Coscomatepec	12/Sep/2009	Heavy rains	Damage to highways and roads
Coscomatepec	06/Jan/2010	Cold front	No Data
Coscomatepec	19/Sep/2010	Heavy rains	Victims, damages in all public services, damages to agriculture and livestock due to Hurricane Karl -category 3.
Coscomatepec	09/Aug/2012	Heavy rains	Damage to highways and roads due to tropical storm Ernesto
Coscomatepec	23/Sep/2013	Heavy rains	Hundreds of homes affected. Roads and bridges damaged by a cold front

Fuente: LaRed, 2019

Supplementary Material 3. Climate change scenarios of precipitation, maximum and minimum temperature with RCP 8.5 for Chocamán, Veracruz.

Scenario	Precipitation	Maximum temperature	Minimum temperature
2010-2030			
2040-2069			
2070-2099			

Supplementary Material 4. Cohorts species by agroforestry design in coffee plots.

Agroforestry design	Cohort	Species with highest importance value	Tree / Plant Density (ha^{1})
Af1	Shade trees	*Lippia myriocephala* Schltdl. & Cham	88
		Inga vera Willd	96
		Juglans olanchana Standl & L. O. Williams	96
	Coffee	*Coffea arabica* L	2600
	Living barriers	Bursera sp.	1500
Af2	Shade trees	*Acrocarpus fraxinifolius* Wight	32
		Inga vera Willd	72
		Juglans olanchana Standl & L. O. Williams	80
	Coffee	*Coffea arabica* L	2800
	Banana tree	*Musa acuminata* Colla	1250
	Living barriers	Bursera sp.	1600
Af3	Shade trees	*Lippia myriocephala* Schltdl. & Cham	40
		Inga vera Willd	38
	Coffee	*Coffea arabica* L	3100
	Banana tree	*Musa acuminata* Colla	1650
	Living fences	Inga sp.	80

Agroforestry design 1 (Af1): Coffee with shade trees and living barriers; Agroforestry design 2 (Af2): Coffee with shade trees, banana and living barriers; and Agroforestry design 3 (Af3): Coffee with shade trees, banana and living fences.

Supplementary Material 5. Water balance variables: current and future monthly humidity index and soil moisture storage, RCP 8.5 by 2099.

Month	Monthly humidity index				
	Current	CNRM	GFDL	HADGEM	MPI
January	Humid	Intermediate	Intermediate	Intermediate	Dry
February	Intermediate	Intermediate	Intermediate	Intermediate	Dry
March	Dry	Intermediate	Dry	Intermediate	Dry
April	Dry	Intermediate	Dry	Intermediate	Dry
May	Intermediate	Humid	Intermediate	Humid	Dry
June	Humid	Humid	Humid	Humid	Humid
July	Humid	Humid	Humid	Humid	Intermediate
August	Humid	Humid	Humid	Humid	Intermediate
September	Humid	Humid	Humid	Humid	Humid
October	Humid	Humid	Humid	Humid	Intermediate
November	Humid	Intermediate	Humid	Humid	Dry
December	Humid	Intermediate	Intermediate	Intermediate	Dry
Year	Humid	Humid	Humid	Humid	Intermediate

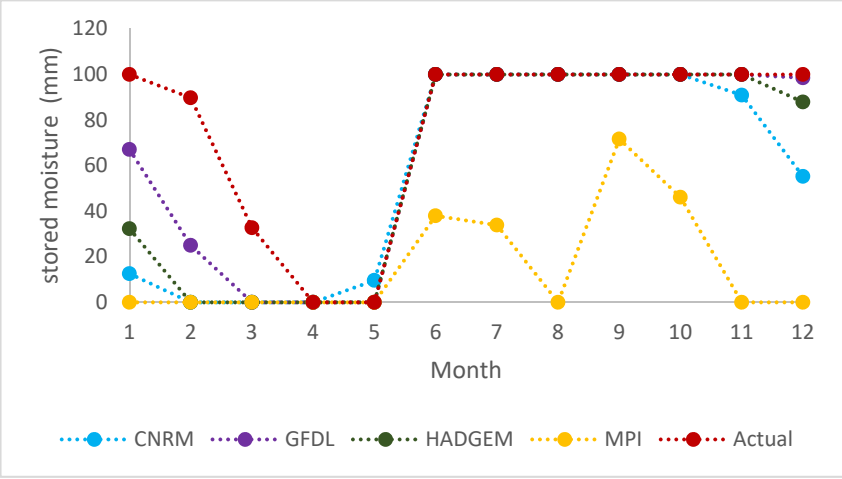


Figure 1. Soil moisture storage (mm) by month, current and climate change scenarios, RCP 8.5 by 2099.

Supplementary Material 6. Main questions guide for interviews

A. Weather and climate threat

Have changes in temperature been detected in recent years?
Have the rains been erratic in recent years?
Have there been torrential rains with floods and landslides?
Have there been droughts () or heat waves () in recent years?
Have there been any changes in dog days or *canícula* season?
Has the force and frequency of strong winds increased?
Has snowfall (), frost () or hail () occurred out of season and at a higher () or lower intensity ()?
Have cold fronts increased in recent years?

B. Impact on the agricultural development of coffee

Is there irregular flowering on coffee plants?
Is there an increase in the fall of flowers and coffee fruits?
Has there been any damage to the coffee bean? Which?
Have impacts been observed on coffee leaves? Which?
At what time of year was the main damage to the coffee plantation observed?
What diseases and pests have occurred in recent years?
In recent years, has the damage of pests and diseases in coffee plantations increased? Which?
At what time of year have pests and diseases increased? Which?
Do the soils show signs of erosion?

C. Adaptation actions that are being implemented individually or collectively

Is your coffee plantation in full sun (), with little shade (<20%) () or with excess shade (> 70%)?
Do you use diversified trees and shrubs within your plot?
What management practices do you give to the trees and shrubs used for shade in the coffee plantation?
Is there a preferred tree or shrub species for shade in the coffee plantation? Why?
What tree or shrub species do you avoid using? Why?
What strategies at the individual level have you implemented to reduce the impact of the change in climate variables in your coffee plantations? Mention what weather threat you are implementing it for.
What strategies have you implemented at the collective level to reduce the impact of the change in climate variables in your coffee plantations? Mention what weather threat you are implementing it for.
What strategies do you use to reduce soil erosion if it exists on your plots?
What practices do you carry out at the organization level to reduce water use?
What practices do you carry out at the individual level to reduce water use?
What other aspects do you think should be strengthened to continue producing coffee?

References

Díaz, J. A. B. O., A. G. Naranjo, N. J. V. Mancera, T. H. Tejeda, M. de Jesús Ordóñez Díaz, and R. Dávalos-Sotelo. 2015. Density of Mexican Woods by Vegetation Type Based on J. Rzedowski's Classification: Compilation. Madera Bosques 21:77–126.

Kuyah, Shem, Johannes Dietz, Catherine Muthuri, Ramni Jamnadass, Peter Mwangi, Richard Coe, and Henry Neufeldt. 2012. Allometric Equations for Estimating Biomass in Agricultural Landscapes: I. Aboveground Biomass. Agriculture, Ecosystems and Environment 158: 216–24.

LaRed, 2019. Inventario histórico de desastres en México. Desinventar, LaRed. Corporación OSSO – Colombia. https://www.desinventar.org/es/database

Negash, Mesele and Markku Kanninen. 2015. Modeling Biomass and Soil Carbon Sequestration of Indigenous Agroforestry Systems Using CO2FIX Approach. Agriculture, Ecosystems and Environment 203:147–55.

Negash, Mesele, Mike Starr, and Markku Kanninen. 2013. Allometric Equations for Biomass Estimation of Enset (Ensete Ventricosum) Grown in Indigenous Agroforestry Systems in the Rift Valley Escarpment of Southern-Eastern Ethiopia. Agroforestry Systems 87(3):571–81.

Negash, Mesele, Mike Starr, Markku Kanninen, and Leakemaraiam Berhe. 2013. Allometric Equations for Estimating Aboveground Biomass of Coffea Arabica L. Grown in the Rift Valley Escarpment of Ethiopia. Agroforestry Systems 87(4):953–66.

Nyombi, K., P. J. A. Van Asten, P. A. Leffelaar, M. Corbeels, C. K. Kaizzi, and K. E. Giller. 2009. Allometric Growth Relationships of East Africa Highland Bananas (Musa AAA-EAHB) Cv. Kisansa and Mbwazirume. Annals of Applied Biology 155(3):403–18.

Segura, Milena, Markku Kanninen, and Damaris Suárez. 2006. Allometric Models for Estimating Aboveground Biomass of Shade Trees and Coffee Bushes Grown Together. Agroforestry Systems 68(2):143–50.