Supplementary Materials: Capturing Agroecosystem Vulnerability and Resilience

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Box 1—Details of Data Collection and Modelling

1.1. Variables Collected

To characterize the current performance of the selected dairy farms, the management of the farms was monitored between July 2009 and June 2010. The information collected every fortnight included social, economic, and environmental aspects, of all farm management practices implemented in the crop and animal subsystems. In the crop subsystem, the information gathered was related to forage production and utilization, inputs, and labor demand, costs, and allocation. In the animal subsystem, it included information pertaining to herd structure, milk production and marketing, body weight, dry matter intake (DMI), labor requirement, and sanitary and reproductive management. Additionally, to characterize soil physical and chemical properties and soil losses in grazing and cropping lands, soil sampling, groundcover, and runoff measurements were carried out during the rainy season. Samples of grazed and conserved forage, feedstuffs, milk produced, feces, urine, runoff, and soil were submitted to chemical analysis. It included crude protein (CP), nitrogen (N), phosphorus (P), potassium (K) content, total ashes, soil bulk density, and organic C content, depending on the type of sample. One weather station Davis Vantage Pro2™ was installed in each farm to record information related to temperature (°C) and rainfall (mm).

1.2. Variable Estimated and Assumptions

Some variables required to explore the alternatives were estimated indirectly or taken from the literature. Biological and non-symbiotic fixation were results reported by Cleveland et al. (1999) and Fatima et al. (2008). Atmospheric deposition of N was indirectly estimated according to Galloway et al. (2008), and P and K deposition were calculated as a function of the precipitation and their specific factors (Smaling and Fresco, 1993). Parameters to estimate DMI, ME, and CP requirements per type of animals of the herd structure were based on NRC standards (NRC 1989, 2001). ME requirements for lactating cows were estimated using an equation built specifically for the type of animals and management condition present of region (Améndola, 2008).

In the economic analysis, it was assumed that the opportunity cost of owned optimal solutions optimal solutions land was on average the rental price per unit of land in the study region, while for the estimation of the family labor cost, it was considered the salary of a possible alternative occupation based on the skills of each family member that worked in the farm.

Table S1. Forage maize production, crop management, and precipitation on medium intensive family-based (FB) and semi-specialized (SS) dairy farms in Marcos Castellanos, Michoacán, Mexico, in 2008–2009 and 2009–2010.

Variable	FB		SS	
	2008–2009	2009–2010	2008–2009	2009–2010
Seed maize variety	Mareño	Barriga	Creole seeds	Matador
Seeding (kg·ha^{-1})	29.1	36.4	21.6	27.6
Nitrogen (kg·ha^{-1})	104	129	182	217
Phosphorus (kg·ha^{-1})	10.4	41.8	0.0	0.0
Forage maize yield (t·DM·ha^{-1})	10.6	16.0	11.1	16.3
Fall armyworm	Lack of control	Controlled	Lack of control	Controlled
Precipitation (mm)	717	605	678	652

Table S2. Decision variables (inputs and constrains) modified during the exploration of alternatives for family-based (FB) and semi-specialized (SS) dairy farms systems located in Marcos Castellanos, Michoacán, Mexico.

Decision Variable	**Original** §	**Minimum** §§	**Maximum** §§
FB			
Inputs of the model for resilience analysis under reduction of forage maize production (shock effect)			
Maize silage (kg·DM)	19,710 (0.95)	0 (0)	20,000 (1)
Barley forage (kg·DM)	0 (0)	0 (0)	6541 (1)
Milk production (kg·cow^{-1}·d^{-1})	10	7	13
Replacement rate	0.25	0.19	0.28
Outcomes of the model			
Intake in rainy season (%)	−24	−999	0
ME in rainy season (%)	−5	−10	10
CP in rainy season (%)	−9	−10	10
Intake in dry season (%)	−28	−999	0
ME in dry season (%)	12	−10	12.5
CP in dry season (%)	−13	−13.5	10
OM balance (kg·ha^{-1})	−816	−816	9999
N (kg·ha^{-1})	37	0	999
Labor balance (h)	−479	−719	−335
Feeding costs (US $)	19,794	7918	29,691
Operating profit (US $)	8958	−1545	77,251
SS			
Inputs of the model for resilience analysis under reduction of forage maize production (shock effect)			
Maize silage (kg·DM)	93,873 (0.95)	0 (0)	93,900 (1)
Barley forage (kg·DM)	0 (0)	0 (0)	27,057 (1)
Milk production (kg·cow^{-1}·d^{-1})	9	6.3	11.7
Replacement rate	0.25	0.19	0.28
Outcomes of the model			
Intake in rainy season (%)	−3	−999	0
ME in rainy season (%)	30	−10	30.5
CP in rainy season (%)	37	−5	36.8
Intake in dry season (%)	−18	−999	0
ME in dry season (%)	21	−10	21.4
CP in dry season (%)	−1	−11	10
OM balance (kg·ha^{-1})	−685	−686	9999
N (kg·ha^{-1})	49	0	999
Labor balance (h)	4361	2340	6083
Feeding costs (US $)	99,358	39,743	149,038
Operating profit (US $)	−1019	−1545	77,251

§ The data without brackets are the absolute values of the variables of the original farm configuration, and the data between brackets are the proportion of the variable used in dry season; §§ The numbers without brackets are the threshold values (minimum and maximum) of the variables in their original units, and the numbers between brackets are the threshold values (minimum and maximum) for the proportion to be used in dry season.

1.3. Exploratory Tool Used

The inputs required for the model can be grouped in: biophysical environment (soil and climate); socio-economic (costs, and labor demand and prices); crops (diversity, production, nutrient composition, labor demand and costs); crop products (external feeding sources) (diversity, demand, costs, and nutrient composition); groups of animals and herd composition (diversity, management, productivity, and nutrient requirements); type of products of the farm (diversity, destination, prices, and composition); manure sources, deposition, and use (production, management, and use efficiency); external sources of mineral nutrients (diversity, amounts, composition, costs, and use efficiency), and physical assets (buildings and machinery).

Flows and balances of OM, N, P and K through and from a farm, nutrient balances of ME and CP, herd DMI, manure production and composition, and labor and economic balances are the outcomes of a static farm balance of the model. These variables were related to whole farm area, land use, crop products destination, animal requirement and production, and inputs and outputs of the farms.

For the exploration process, all the variables constrained are considered by the model as the decision variables to search for optimal solutions based on the desired objectives. These objectives can be to minimize or to maximize specific outcomes. A complete description of the model was presented by Groot et al. (2012).