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*Supplement of*

## **Examining the sustainability and development challenge in agricultural-forest frontiers of the Amazon Basin through the eyes of locals**

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**The following supplements accompany the article**

**Table S1.** Structural metrics of Fuzzy Cognitive Maps analysed.

Structural Metric	Definition	Source
Outdegree ( $od(v_i)$ )	Cumulative total of transmitted connection weights from each component (horizontal cumulative sum within adjacency matrix).	Wasserman and Faust 1994
Indegree ( $id(v_i)$ )	Cumulative total of received connection weights to each component (vertical sum within adjacency matrix).	Wasserman and Faust 1994
Receiver variables ( $R$ )	Components that receive connections from other components but does not influence others through outward connections (components with zero $od(v_i)$ )	Özesmi and Özesmi 2003
Transmitter variables or drivers ( $T$ )	Components that solely influences other components through outward connections but does not receive connections (components with zero $id(v_i)$ )	Özesmi and Özesmi 2003
Ordinary variables ( $O$ )	Components that both influence and are influenced upon within the system	Özesmi and Özesmi 2003
Density ( $D$ )	Number of connections ( $C$ ) divided by the maximum number of possible connections between a number $N$ of components	Devisscher et al. 2016; Hage and Harary, 1983
	$D = \frac{C}{N(N-1)}$	
Complexity ( $CM$ )	Number of receiver components ( $R$ ) divided by the number of transmitters ( $T$ ). A receiver being a	Devisscher et al. 2016; Özesmi and Özesmi 2004
	$CM = \frac{R}{T}$	
Betweenness ( $Bw$ )	Betweenness is a centrality measure of influence of a node within a network. This measure quantifies the number of times a node acts as an intermediary along the shortest path between two other nodes.	Freeman, 1977; Brandes, 2001
Page Rank ( $PR$ )	Used to determine a node's relevance or importance. PageRank value for a node $u$ is dependent on the PageRank values for each node $v$ contained in the set $Bu$ (the set containing all nodes linking to node $u$ ), divided by the number $L(v)$ of links from page $v$ .	Page et al., 1999; Berkhim, 2005; this study
	$PR(u) = \sum_{v \in B_u} \frac{PR(v)}{L(v)}$	









**Table S4.** Preferred changes in components in Guarayos and Tapajós.

<b>Guarayos</b>		<b>Tapajós</b>	
<b>Component</b>	<b>Desired Change</b>	<b>Component</b>	<b>Desired Change</b>
Agricultural Expansion	Decrease	Access to Viable Economic Activities and Finance	Negative
Agricultural Intensification	Neutral	Agricultural Expansion	Negative
Application of Agricultural Law	Positive	Climate Change	Negative
Application of Forest Law	Positive	Contamination	Negative
Biodiversity Loss	Negative	Deforestation	Negative
Climate Change	Negative	Depopulation of Rural Areas	Negative
Compliance with Land Zoning	Positive	Environmental Monitoring	Positive
Contamination	Negative	Financial Aid and Equality	Positive
Deforestation	Negative	Forest Fires	Negative
Destruction of Environmental Services	Negative	Forest Products Value	Positive
Destruction of Pampas	Negative	Illegal Logging	Negative
Fires	Negative	Illegal Mining	Negative
Grazing Expansion	Negative	Incomplete Production Chains	Negative
Illegal Hunting and Fishing	Negative	Positive in Amazon Population	Negative
Illegal Logging	Negative	Infrastructure Projects	Neutral
Illegal Mining	Negative	International Interest to Conserve Amazon	Positive
Immigration	Negative	Lack of Efficiency in Policies for Subsistence Farming	Negative
Inequality in Benefits	Negative	Lack of Environmental Awareness	Negative
Lack of Awareness of Environmental Problems	Negative	Lack of Governmental Co-ordination	Negative
Lack of Credit	Negative	Lack of Protection of Traditional Forest Communities	Negative
Lack of Understanding, Application and Coordination of Laws	Negative	Lack of Public Policy	Negative
Land Encroachment	Negative	Lack of Sustainable Development Models	Negative
Land Trafficking	Negative	Lack of Technical Training and Assistance	Negative
Loss of Lakes and Natural Springs	Negative	Loss of Biodiversity	Negative
Loss of Subsistence Agriculture in Guarayos Communities	Negative	Loss of Environmental Services	Negative
Lower Crops Yields	Negative	Opportunities to Sell Environmental Services	Positive
Poor Administration by Community Leaders	Negative	Population Purchasing Power	Positive
Poverty	Negative	Pressure from External Actors (agribusiness)	Negative
Soil Erosion	Negative	Social Organisation and Social Political Participation	Positive
		Technical and Productive Capacity	Positive
		Technology Supplied for Sustainable Land Use	Positive
		Use of Agrochemicals	Neutral

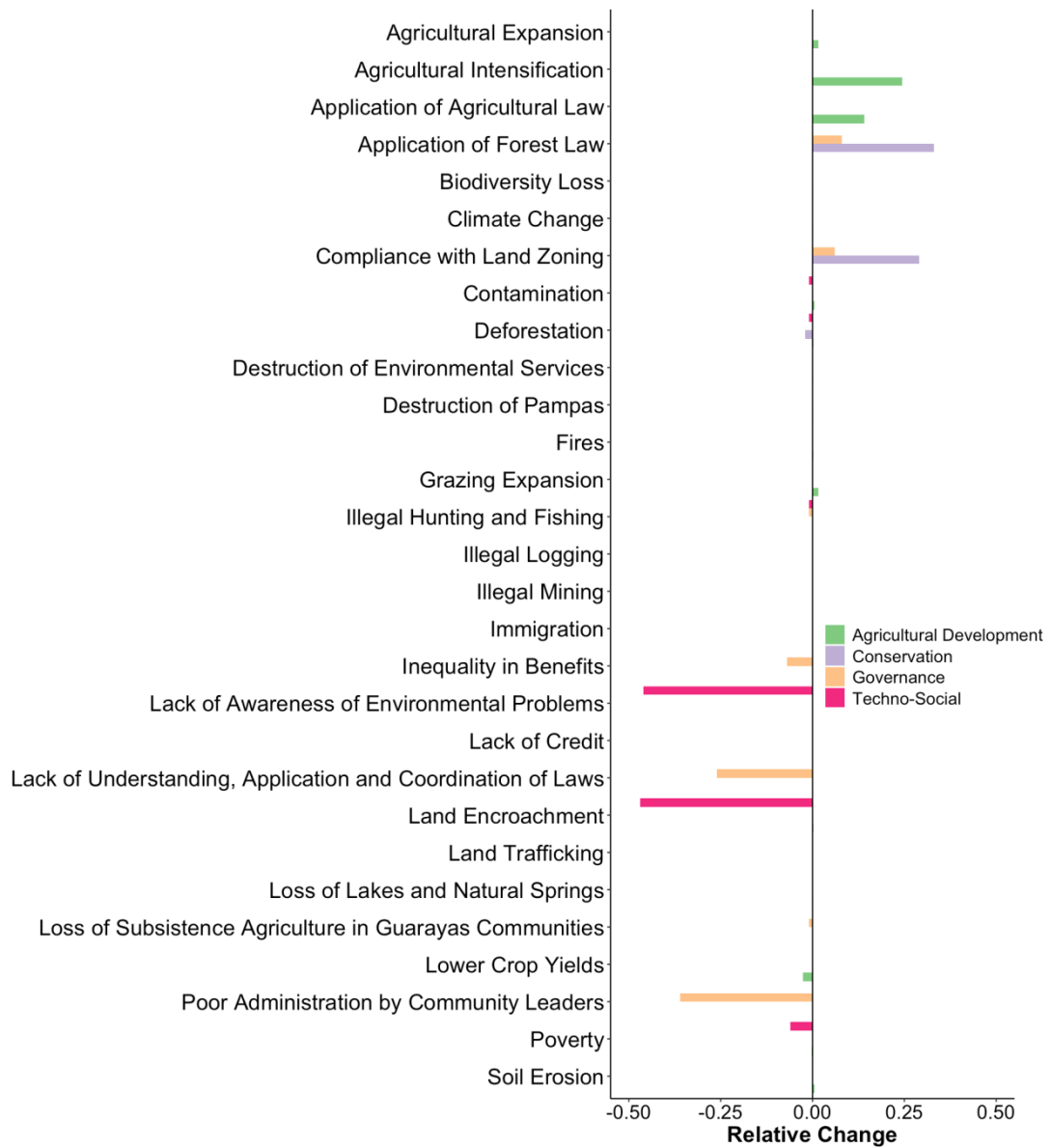
**Table S5.** Component Indices for Guarayos.

<b>Component</b>	<b>Outdegree</b>	<b>Indegree</b>	<b>Page Rank</b>	<b>Betweenness</b>	<b>Component Type</b>
Agricultural Expansion	1.75	2.05	0.037	0.056	Ordinary
Agricultural Intensification	1.10	0.50	0.015	0.008	Ordinary
Application of Forest Law	0.50	0.90	0.014	0.007	Ordinary
Application of INRA	1.40	0.00	0.011	0.000	Transmitter
Biodiversity Loss	0.00	1.75	0.117	0.000	Receiver
Climate Change	0.80	0.50	0.026	0.030	Ordinary
Compliance with Land Zoning	0.20	0.70	0.014	0.007	Ordinary
Contamination	0.10	2.55	0.080	0.009	Ordinary
Deforestation	4.70	3.10	0.110	0.217	Ordinary
Destruction of Environmental Services	0.00	0.90	0.026	0.000	Receiver
Destruction of Pampas	0.00	0.50	0.024	0.000	Receiver
Fires	0.85	1.40	0.031	0.034	Ordinary
Grazing Expansion	1.60	0.50	0.015	0.010	Ordinary
Illegal Hunting and Fishing	0.85	0.75	0.053	0.021	Ordinary
Illegal Logging	0.50	0.20	0.050	0.083	Ordinary
Illegal Mining	1.10	0.00	0.011	0.000	Transmitter
Immigration	0.90	0.90	0.020	0.020	Ordinary
Inequality in Benefits	0.90	0.90	0.020	0.019	Ordinary
Lack of Awareness of Environmental Problems	0.50	0.00	0.011	0.000	Transmitter
Lack of Credit	0.75	0.00	0.011	0.000	Transmitter
Lack of Understanding, Application and Coordination of Laws	1.85	0.00	0.011	0.000	Transmitter
Land Encroachment	0.25	0.50	0.021	0.000	Ordinary
Land Trafficking	0.90	0.00	0.011	0.000	Transmitter
Loss of Lakes and Natural Springs	0.00	0.60	0.026	0.000	Receiver
Loss of Subsistence Agriculture in Guarayos Communities	0.90	0.90	0.028	0.034	Ordinary
Lower Crop Yields	0.60	1.90	0.068	0.098	Ordinary
Poor Administration by Community Leaders	0.90	0.00	0.011	0.000	Transmitter
Poverty	0.70	1.50	0.092	0.139	Ordinary
Soil Erosion	0.50	1.60	0.035	0.044	Ordinary



**Table S6.** Component indices for Tapajós.

Component	Outdegree	Indegree	Page Rank	Betweenness	Component Type
Access to Viable Economic Activities and Finance	1.25	0.90	0.014	0.002	Ordinary
Agricultural Expansion	1.58	1.38	0.028	0.016	Ordinary
Climate Change	0.25	0.25	0.046	0.000	Ordinary
Contamination	1.50	2.25	0.043	0.005	Ordinary
Deforestation	2.13	7.00	0.164	0.088	Ordinary
Depopulation of Rural Areas	0.00	0.50	0.017	0.000	Receiver
Environmental Monitoring	1.73	0.83	0.013	0.005	Ordinary
Financial Aid and Equality	0.75	0.13	0.013	0.001	Ordinary
Forest Fires	0.75	1.08	0.089	0.002	Ordinary
Forest Products Value	0.50	1.50	0.033	0.011	Ordinary
Illegal Logging	0.50	1.15	0.023	0.002	Ordinary
Illegal Mining	0.75	0.00	0.011	0.000	Transmitter
Incomplete Production Chain	0.75	0.75	0.014	0.001	Ordinary
Increase in Amazon Population	1.50	0.00	0.011	0.000	Transmitter
Infrastructure Projects	1.15	1.65	0.027	0.017	Ordinary
International Interest to Conserve Amazon	0.50	0.00	0.011	0.000	Transmitter
Lack of Efficiency in Policies for Subsistence Farming	2.40	0.00	0.011	0.000	Transmitter
Lack of Environmental Awareness	1.50	0.00	0.011	0.000	Transmitter
Lack of Governmental Co-ordination	1.95	0.00	0.011	0.000	Transmitter
Lack of Protection of Traditional Forest Communities	0.75	0.00	0.011	0.000	Transmitter
Lack of Public Policy	0.90	0.75	0.017	0.003	Ordinary
Lack of Sustainable Development Models	1.50	0.25	0.016	0.004	Ordinary
Lack of Technical Training and Assistance	0.75	0.75	0.014	0.005	Ordinary
Loss of Biodiversity	0.00	2.00	0.083	0.000	Receiver
Loss of Environmental Services	0.00	2.25	0.140	0.000	Receiver
Opportunities to Sell Environmental Services	0.50	0.00	0.011	0.000	Transmitter
Population Purchasing Power	0.50	3.00	0.041	0.013	Ordinary
Pressure from External Actors	0.90	0.25	0.013	0.004	Ordinary
Social Organisation and Social Political Participation	1.50	0.25	0.014	0.002	Ordinary
Technical and Productive Capacity	0.50	0.75	0.013	0.002	Ordinary
Technology Supplied For Sustainable Land Use	0.38	0.00	0.011	0.000	Transmitter
Use of agrochemicals	0.75	0.75	0.023	0.006	Ordinary



**Figure S1.** Relative change of individual component values in Guarayos under the conditions of the four scenarios compared with baseline.



**Figure S2.** Relative change of individual component values in Tapajós under the conditions of the four scenarios compared with baseline.

## References

- Berkhim, P.: A survey on PageRank computing, *Internet Mathematics*, 2, 73–120, <https://doi.org/10.1080/15427951.2005.10129098>, 2005
- Brandes, U.: A Faster Algorithm for Betweenness Centrality, *J. Math. Sociol.*, 25, 163–177, <https://doi.org/10.1080/0022250X.2001.9990249>, 2001.
- Devisscher, T., Boyd, E., and Malhi, Y.: Anticipating future risk in social-ecological systems using fuzzy cognitive mapping: The case of wildfire in the Chiquitania, Bolivia, *Ecol. Soc.*, 21, 18, <https://doi.org/10.5751/ES-08599-210418>, 2016.
- Freeman, L. C.: A Set of Measures of Centrality Based on Betweenness, *Sociometry*, 40, 35–41, <https://doi.org/10.2307/3033543>, 1977.
- Hage, P. and Harary, F.: *Structural models in anthropology*, Oxford University Press, New York, USA, 1983.
- Özesmi, U. and Özesmi, S. L.: A Participatory Approach to Ecosystem Conservation: Fuzzy Cognitive Maps and Stakeholder Group Analysis in Uluabat Lake, Turkey, *J. Environ. Manage.*, 31, 518–531, <https://doi.org/10.1007/s00267-002-2841-1>, 2003.
- Özesmi, U. and Özesmi, S. L.: Ecological models based on people's knowledge: A multi-step fuzzy cognitive mapping approach, *Ecol. Model.*, 176, 43–64, <https://doi.org/10.1016/j.ecolmodel.2003.10.027>, 2004.
- Page, L., Brin, S., Motwani, R., and Winograd, T.: *The PageRank citation ranking: Bringing order to the Web*. Technical Report SIDL-WP-1999-0120, Stanford Digital Library, Stanford, USA, 1999.
- Wasserman, S. and Faust, K.: *Social Network Analysis: Methods and Applications*, Cambridge University Press, Cambridge, UK, 1994.