

School of Integrated Climate System Sciences

Un modelo probabilístico para explorar las alteraciones por el cambio climático en la aptitud climática de la tierra para la producción de café (*Coffea arabica* L.)

Leonel Lara Estrada



XXIII
Simposio
Latinoamericano
de Caficultura

Agosto 24th, 2017
San Pedro Sula, Honduras





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Latinoamericano
de Caficultura

Caficultura enfrenta múltiples retos:

- Degradación de suelos
- Plagas y enfermedades
- Cambio climático
- Crisis de precios y costos
- Políticas y legislación
- Otros...

Producción sostenible



PLANIFICACIÓN

Evaluación de la Tierra

- 1) Cual es la aptitud actual para producir café?
- 2) Cual es el margen de mejora?
- 3) Como afectaran cambios inducidos o naturales la aptitud actual y futura?



PLANIFICACIÓN

Evaluación de la Tierra

- Diagnostico condición actual
- Herramientas apropiadas para la toma de decisión
- Limitaciones de conocimiento y/o información

Incertidumbre



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Modelos Gráficos Probabilísticos Redes Bayesianas

Bayes' rule

$$P(A|B) = \frac{P(B|A) \times P(A)}{P(B)}$$



Red Bayesiana

Modelo grafico probabilístico que representa un set de variables y sus dependencias condicionales vía un grafico dirigido acíclico

1. Modelo Grafico

B1	0.3
B2	0.7

Nodos: Variables



2. Set de probabilidades condicionales

P(A B)	A1	A2	A3	P
B1	0.76	0.18	0.06	1
B2	0.36	0.48	0.16	1



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ALECA

Agroecological Land Evaluation for *Coffea arabica* L. in Central America

Evaluación agroecológica de la tierra para
Coffea arabica L. en Centroamerica

Lara-Estrada, L., Rasche, L., & Schneider, U. A. (2017). Modeling land suitability for *Coffea arabica* L. in Central America. *Environmental Modelling & Software*, 95, 196-209. <https://doi.org/10.1016/j.envsoft.2017.06.028>



Selección de variables y parametrización

Literatura



Suitability functions (Curvas de respuesta)

Table 1

Agroecological variables selected to describe coffee land suitability in Central America with unsuitable, suboptimal and optimal values as reported in the literature.

Component	Variables	Unit	Unsuitable	Suboptimal	Optimal
Climate	Mean annual temperature	°C	$\leq 10^{1,2}$, $\geq 30^{3,6}$, $> 32^2$	$< 15-16^3$, $< 17-18^4$, $> 23^{3,4}$, $> 26^5$	$18-21^3$, $18-23^4$
	Annual precipitation	mm	$< 1000^7$	$< 1300^8$, $> 3000^{7,9}$	$1550-2000^{10}$, $1600-1800^3$
	Dry season length	# months ≤ 60 mm	$> 6^{11}$	$< 2^{12}$, $5-6^{11}$	$2-4^{13}$, $3-4^{14}$
Soil	pH in H ₂ O	—	$< 4^8$, $> 8^8$	< 5 , > 6.5	$5.5-6.5^9$, $5.2-6.2^{14}$
	Cation exchange capacity	Meq 100g ⁻¹	Sand ($> 30\%$), heavy clay (clay $> 70\%$) ^{12,13}	$< 5^{15}$	$> 22^{15, 16}$
Landform	Texture	Categorical			Loam, clay loam, clay
	Slope	%	$> 50^9$, $> 70^{17}$	$> 40^7$	$0-40^7$
	Aspect	Cardinal directions			East ¹⁸

¹ Larcher (1981), ² Jaramillo and Guzmán (1984), ³ Alégre (1959), ⁴ Camargo (1985) cited by DaMatta and Ramalho (2006), ⁵ Nunes et al. (1973) cited by DaMatta and Ramalho (2006), ⁶ DaMatta and Ramalho (2006), ⁷ ANACAFE (2006), ⁸ Willson (1985), ⁹ Descroix and Wintgens (2004), ¹⁰ Forestier (1969) cited by Willson (1985), ¹¹ Descroix and Wintgens (2004), ¹² Maestri and Barros (1977), ¹³ Haarer (1958), ¹⁴ Robinson 1964 cited by Willson (1985), ¹⁵ Molina and Melendez (2002), ¹⁶ Verheye (2002), ¹⁷ Blanco and Aguilar (2015), ¹⁸ Avelino et al. (2005).

L. Lara Estrada et al. / Environmental Modelling & Software 95 (2017) 196–209

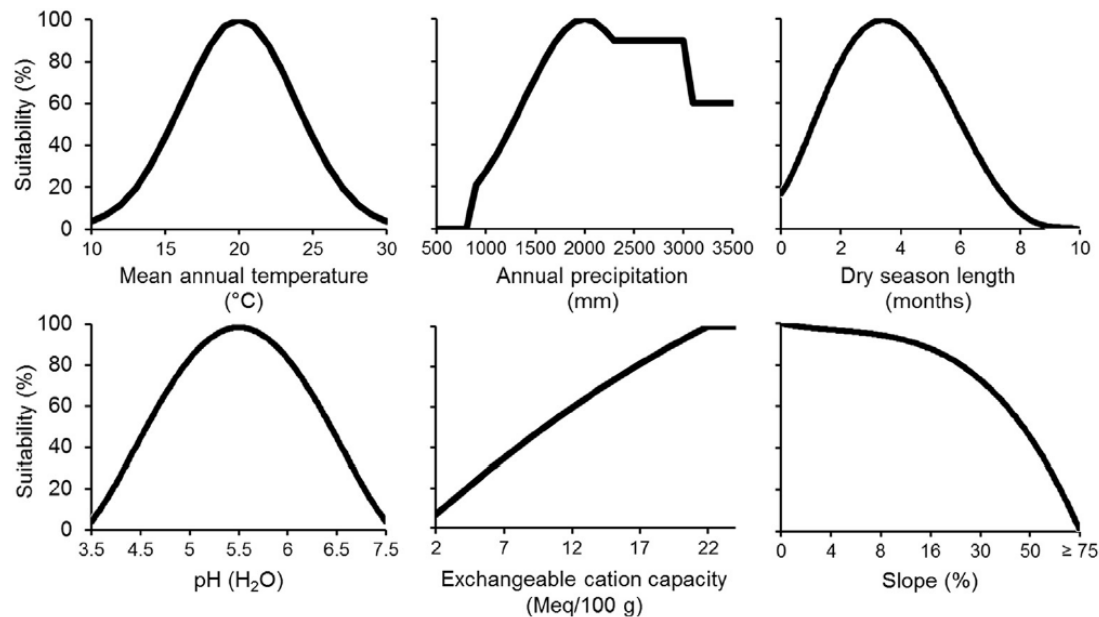


Fig. 2. Graphical display of the suitability functions for continuous variables.



Suitability functions

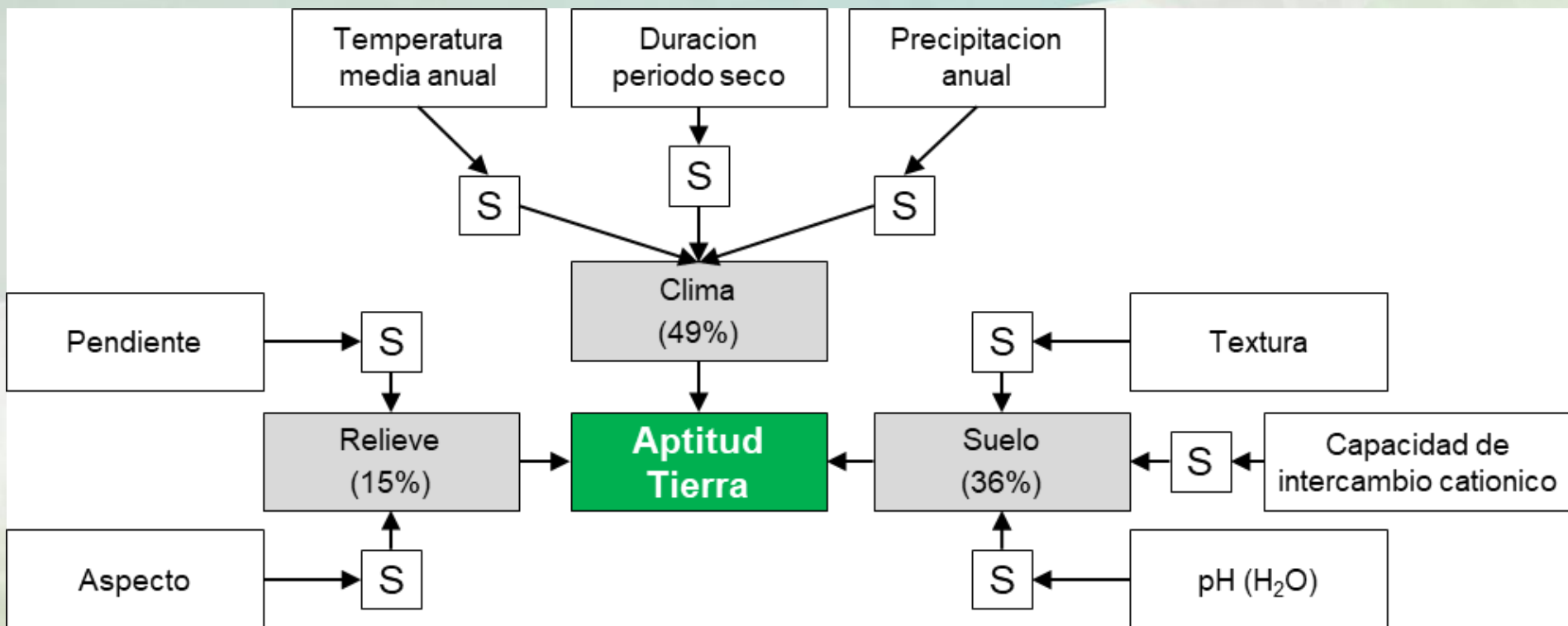
Table 2

Suitability functions of the selected agroecological variables. Suitability scores range from 0 to 100%. The values in the texture table denote that there is a probability of 99% that 'Sand' e.g. only has a suitability of 0–25% for coffee production, and a 1% probability that it is in the range of 25–50%.

Variables	Equations																																																																																			
Mean annual temperature	$S_{ti} = T_i \sim N(\mu, \sigma^2) + T_{\mu} \sim (\mu, \sigma^2) \cdot 100$ <p>Where S_{ti} is the suitability score for a given annual mean temperature in °C (T_i) and is distributed normally with mean $\mu = T_{\mu} = 20$ and variance $\sigma^2 = 3.89$</p>																																																																																			
Annual precipitation	$S_{pi} = \begin{cases} 0, & \text{if } P_i < 800; \\ P_i \sim N(\mu, \sigma^2) + P_{\mu} \sim (\mu, \sigma^2) \cdot 100, & \text{if } P_i < 2300; \\ 90, & \text{if } P_i \leq 3000; \\ 60, & \text{Otherwise} \end{cases}$ <p>Where S_{pi} is the suitability score for a given annual precipitation in mm (P_i) and is distributed normally with mean $\mu = P_{\mu} = 2000$ and $\sigma^2 = 620.48$</p>																																																																																			
Dry season length	$S_{di} = \begin{cases} 0, & \text{if } D_i > 8; \\ 0.252D_i^4 - 3.828D_i^3 + 14.149D_i^2 - 1.458D_i + 60, & \text{Otherwise} \end{cases}$ <p>Where S_{di} is the suitability score for a given dry season length in months (D_i)</p>																																																																																			
Slope	$S_{si} = 0.01 S_i^2 - 2S_i + 100$ <p>Where S_{si} is the suitability score for a given slope in percentage (S_i)</p>																																																																																			
Aspect	$S_{ai} = \begin{cases} 80, & \text{if } A = \text{Flat}; & 90, & \text{if } A = \text{West}; \\ 72, & \text{if } A = \text{Southeast}; & 93, & \text{if } A = \text{Southwest}; \\ 80, & \text{if } A = \text{Northeast}; & 97, & \text{if } A = \text{Northwest}; \\ 80, & \text{if } A = \text{East}; & 100, & \text{if } A = \text{South}; \\ 87, & \text{if } A = \text{North}; & & \end{cases}$ <p>Where S_{ai} is the suitability score for a given slope aspect (A)</p>																																																																																			
pH (H ₂ O)	$S_{phi} = pH_i \sim N(\mu, \sigma^2) + pH_{\mu} \sim (\mu, \sigma^2) \cdot 100$ <p>Where S_{phi} is the suitability score for a given pH (pH_i) and is distributed normally with mean $\mu = pH_{\mu} = 5.5$ and $\sigma^2 = 0.79$</p>																																																																																			
Cation exchange capacity	$S_{ceci} = \begin{cases} 0, & \text{if } CEC_i < 1 \\ 100, & \text{if } CEC_i \geq 22 \\ -0.061CEC_i^2 + 6.114CEC_i - 5.053, & \text{Otherwise} \end{cases}$ <p>Where S_{ceci} is the suitability score for a given cation exchange capacity in meq/100g (CEC_i)</p>																																																																																			
Texture	$S_{ti} =$ <table border="1" style="margin-left: 20px;"> <thead> <tr> <th rowspan="2">Texture</th> <th colspan="5">Suitability (%)</th> </tr> <tr> <th>0 to 25</th> <th>25 to 50</th> <th>50 to 75</th> <th>75 to 90</th> <th>90 to 100</th> </tr> </thead> <tbody> <tr> <td>Sand</td> <td>99</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>Sandy loam</td> <td>99</td> <td>1</td> <td>0</td> <td>0</td> <td>0</td> </tr> <tr> <td>Loamy sand</td> <td>0</td> <td>99</td> <td>1</td> <td>0</td> <td>0</td> </tr> <tr> <td>Loam</td> <td>0</td> <td>0</td> <td>1</td> <td>99</td> <td>0</td> </tr> <tr> <td>Silt loam</td> <td>0</td> <td>0</td> <td>1</td> <td>99</td> <td>0</td> </tr> <tr> <td>Silt</td> <td>0</td> <td>1</td> <td>99</td> <td>0</td> <td>0</td> </tr> <tr> <td>Sandy clay loam</td> <td>0</td> <td>1</td> <td>99</td> <td>0</td> <td>0</td> </tr> <tr> <td>Clay loam</td> <td>0</td> <td>0</td> <td>1</td> <td>99</td> <td>0</td> </tr> <tr> <td>Silty clay loam</td> <td>0</td> <td>0</td> <td>1</td> <td>99</td> <td>0</td> </tr> <tr> <td>Sandy clay</td> <td>0</td> <td>1</td> <td>99</td> <td>0</td> <td>0</td> </tr> <tr> <td>Silty clay</td> <td>0</td> <td>0</td> <td>0</td> <td>1</td> <td>99</td> </tr> <tr> <td>Clay</td> <td>0</td> <td>0</td> <td>0</td> <td>1</td> <td>99</td> </tr> </tbody> </table> <p>Where S_{ti} is the suitability score for a given soil texture (T_i)</p>	Texture	Suitability (%)					0 to 25	25 to 50	50 to 75	75 to 90	90 to 100	Sand	99	1	0	0	0	Sandy loam	99	1	0	0	0	Loamy sand	0	99	1	0	0	Loam	0	0	1	99	0	Silt loam	0	0	1	99	0	Silt	0	1	99	0	0	Sandy clay loam	0	1	99	0	0	Clay loam	0	0	1	99	0	Silty clay loam	0	0	1	99	0	Sandy clay	0	1	99	0	0	Silty clay	0	0	0	1	99	Clay	0	0	0	1	99
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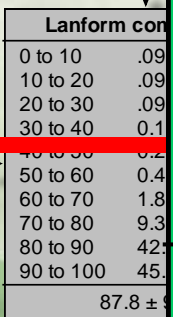
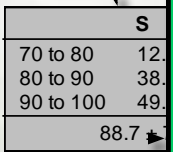
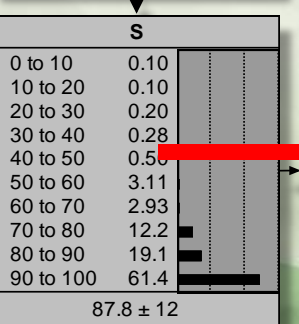
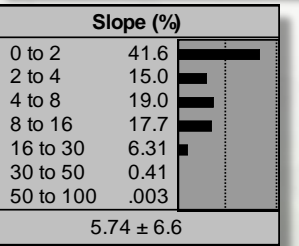
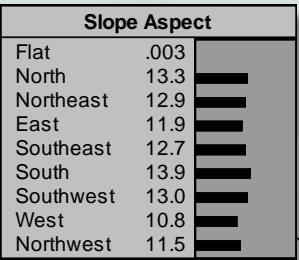
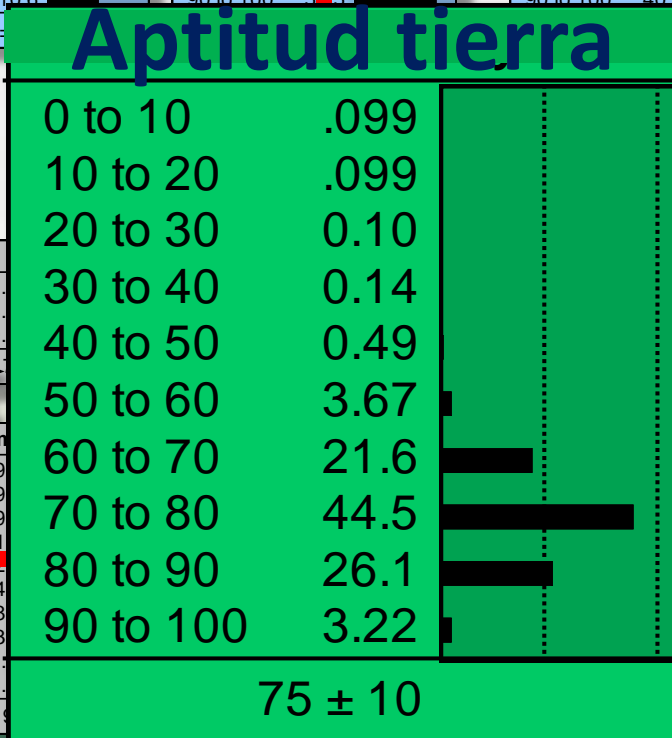
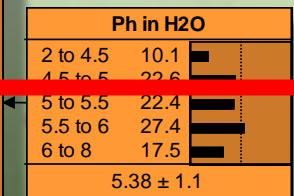
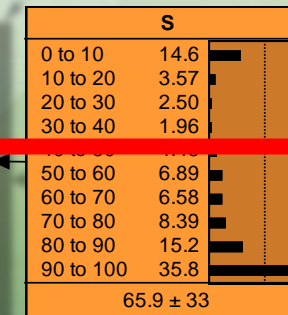
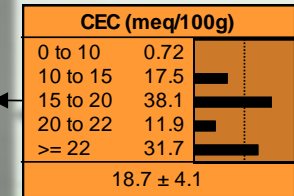
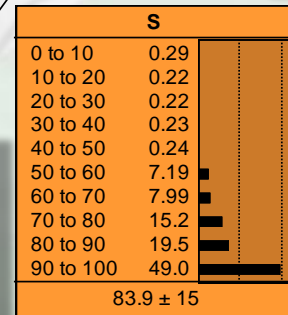
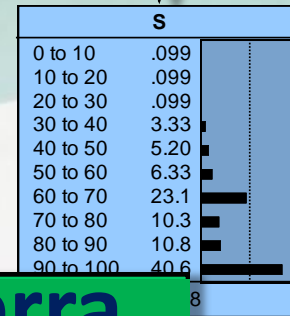
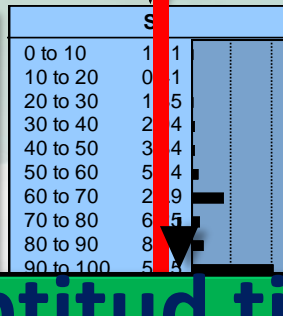
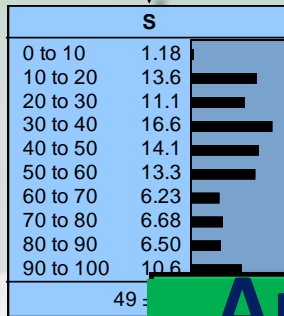
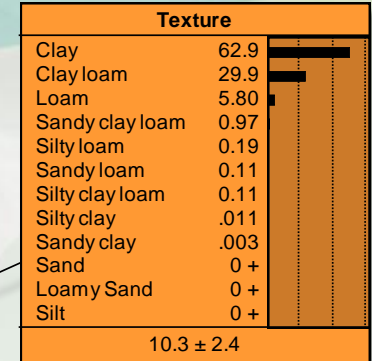
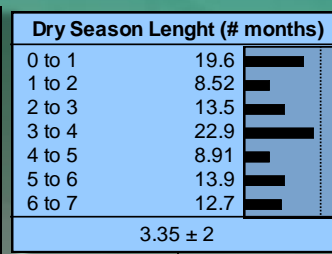
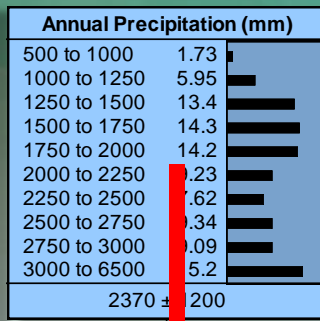
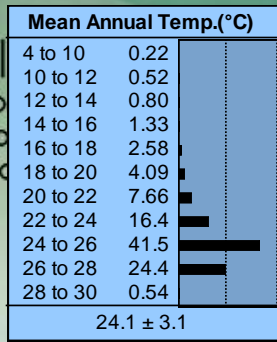


(0 – 100 %)



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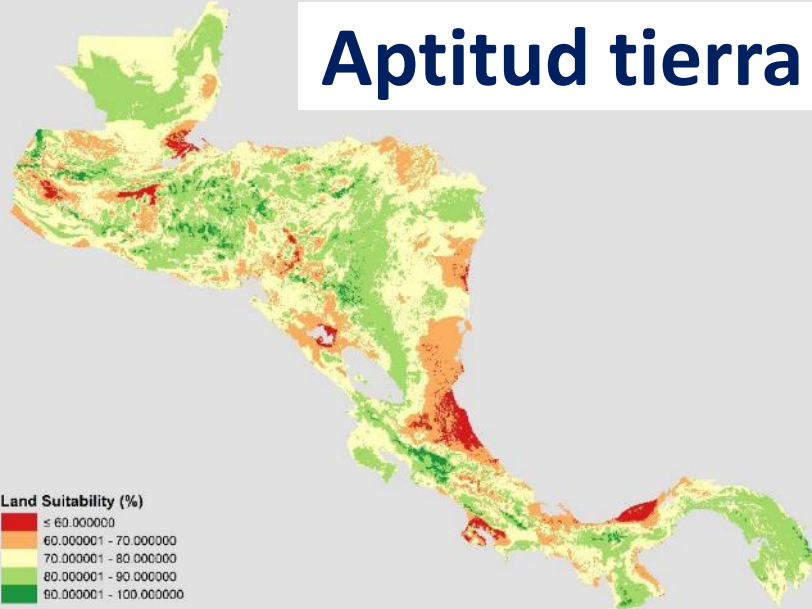
Aptitud actual de la tierra para el cultivo del café en Centroamérica

Aptitud actual de la tierra

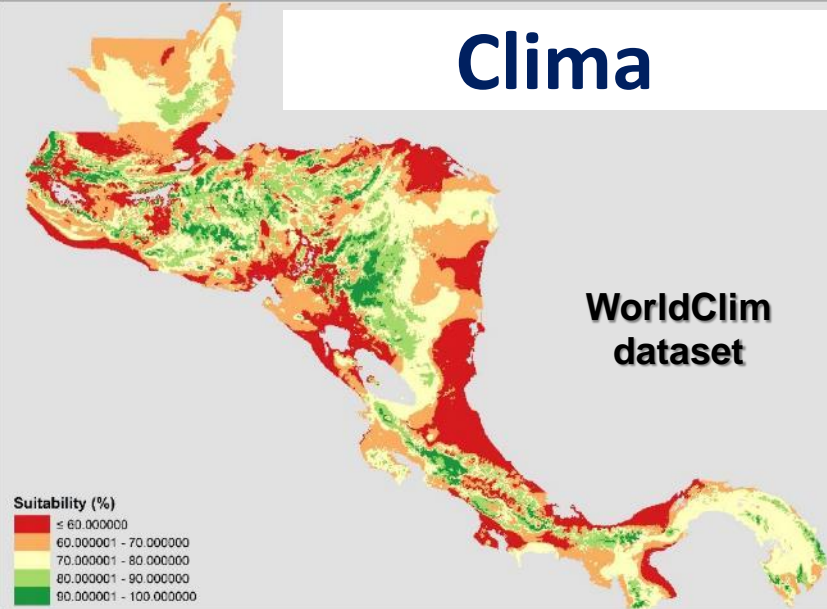
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Interoceánico

Pixel 1 km

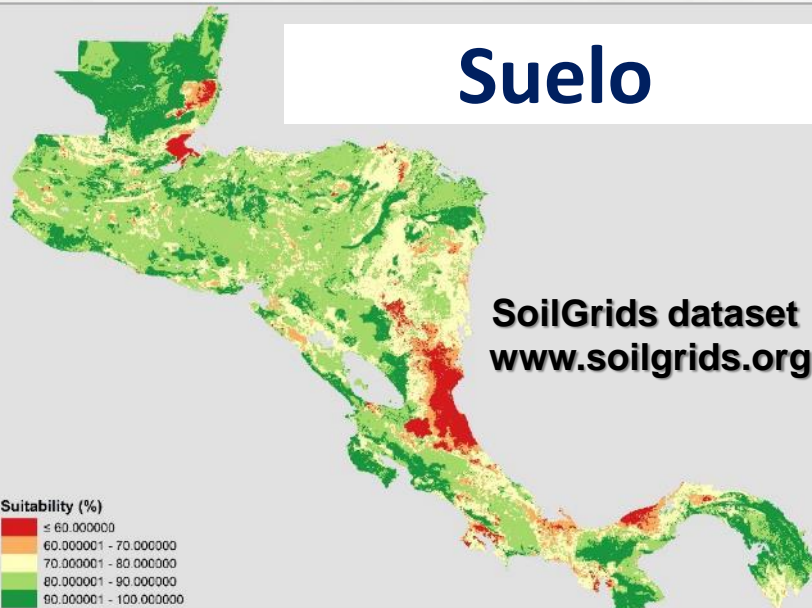
Aptitud tierra



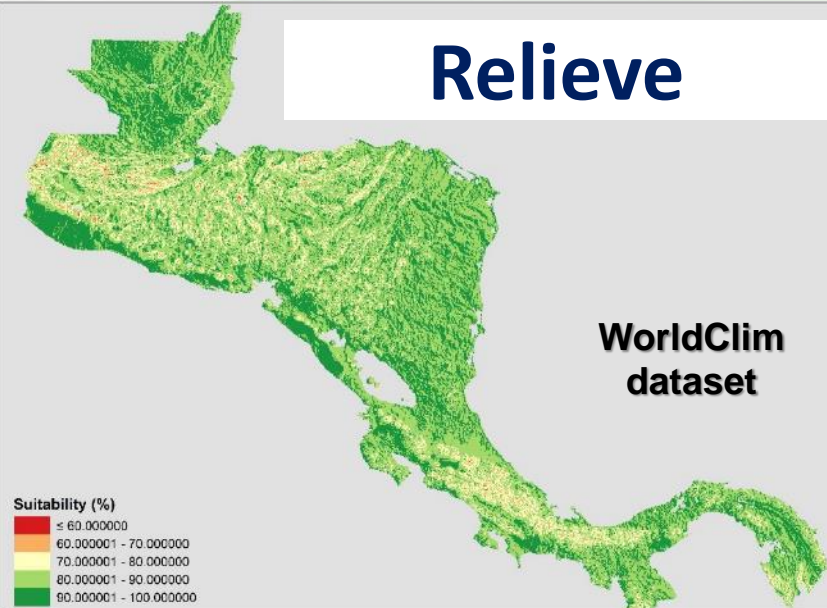
Clima



Suelo



Relieve

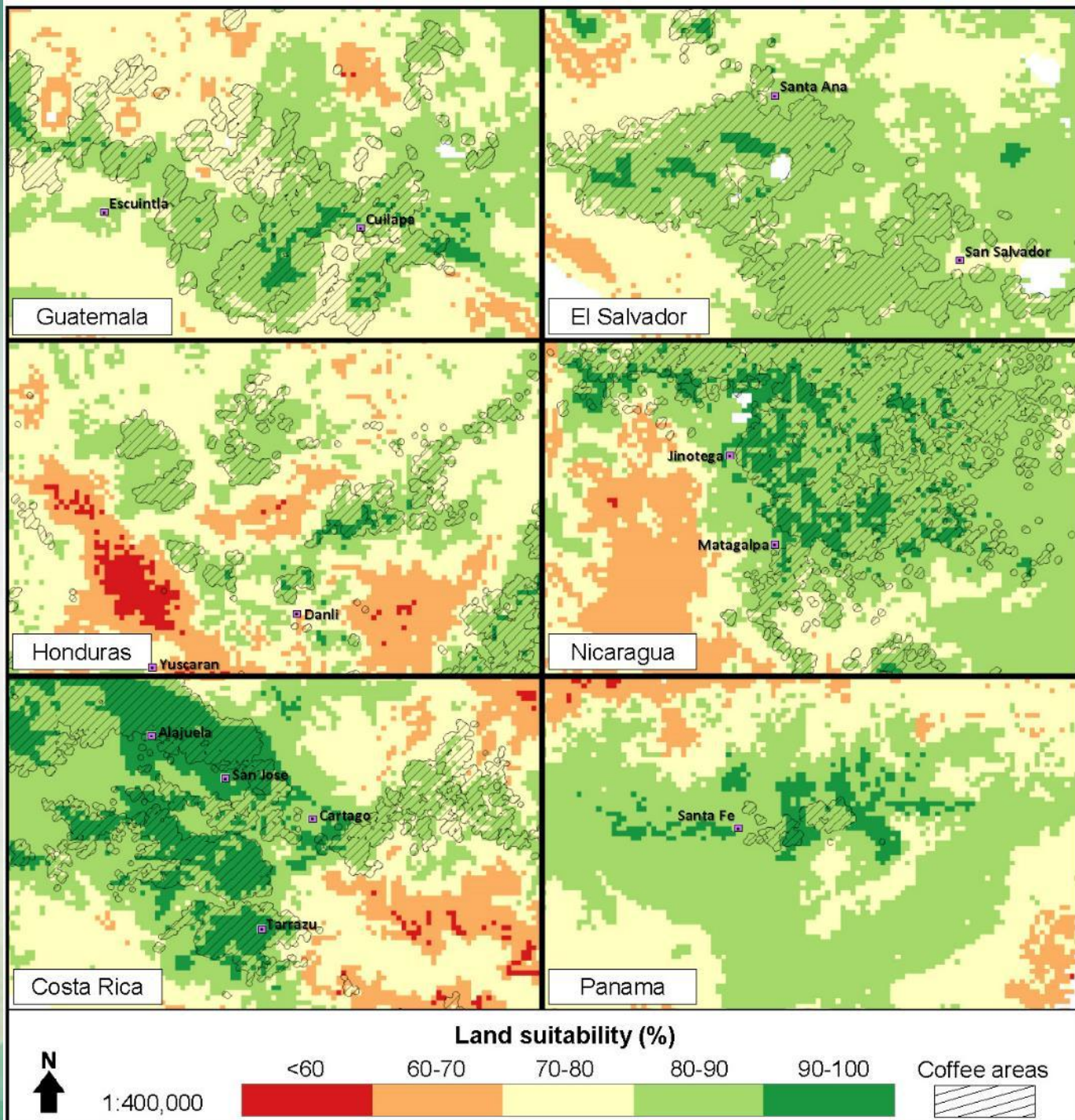




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Areas actuales de café vs. aptitud de la tierra (%)

Pixeles con mayores
puntajes





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Zonas cafetaleras de referencia vs. aptitud de la tierra

Costa Rica:

TAR: Tarrazu

TUR: Turrialba

SCA: San Carlos

Nicaragua:

JIN: Jinotega

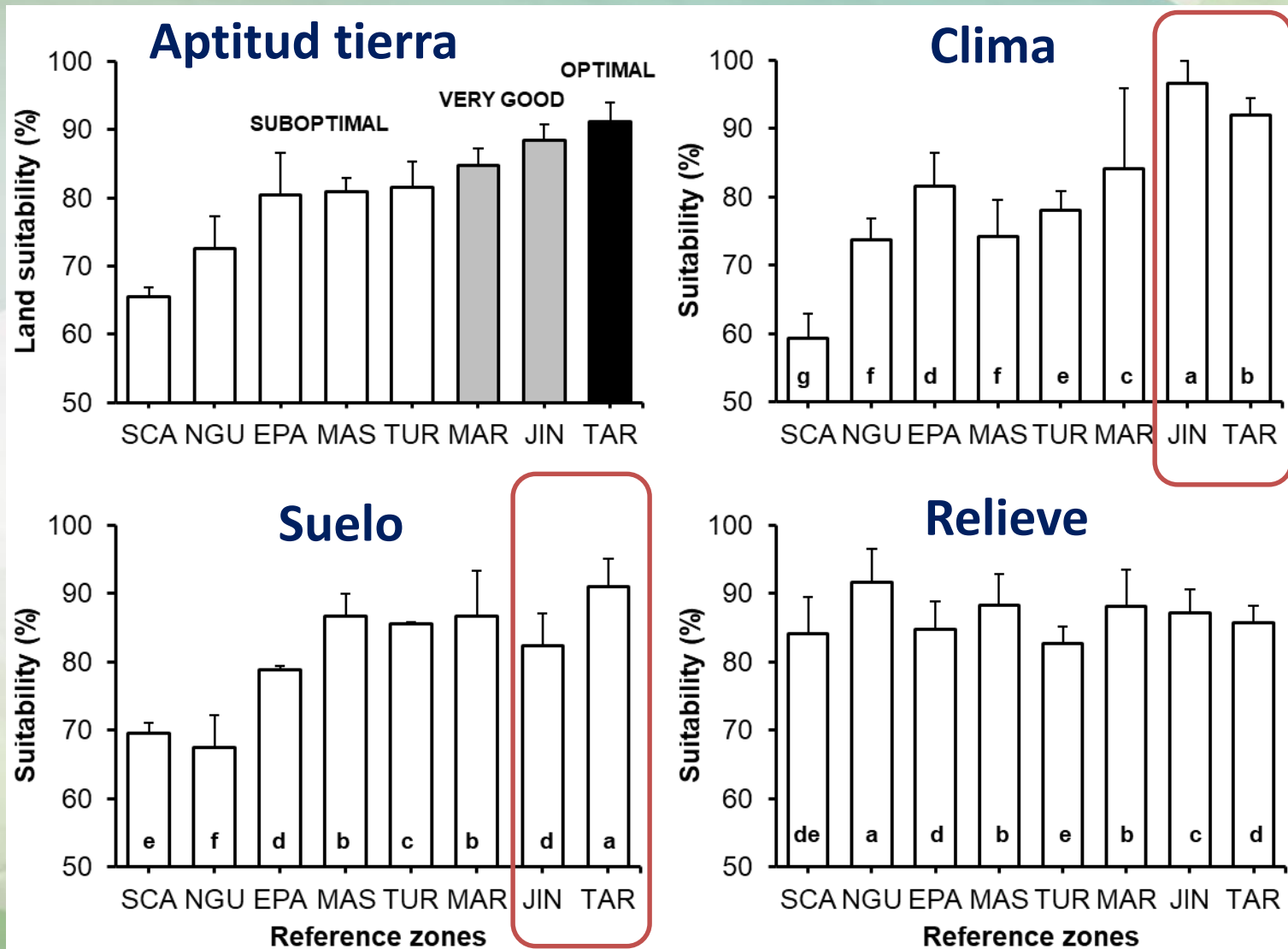
MAS: Masatepe

NGU: Nva. Guinea

Honduras:

MAR: Marcala

EPA: El Paraíso





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Zonas cafetaleras de referencia vs. aptitud de la tierra

Costa Rica:

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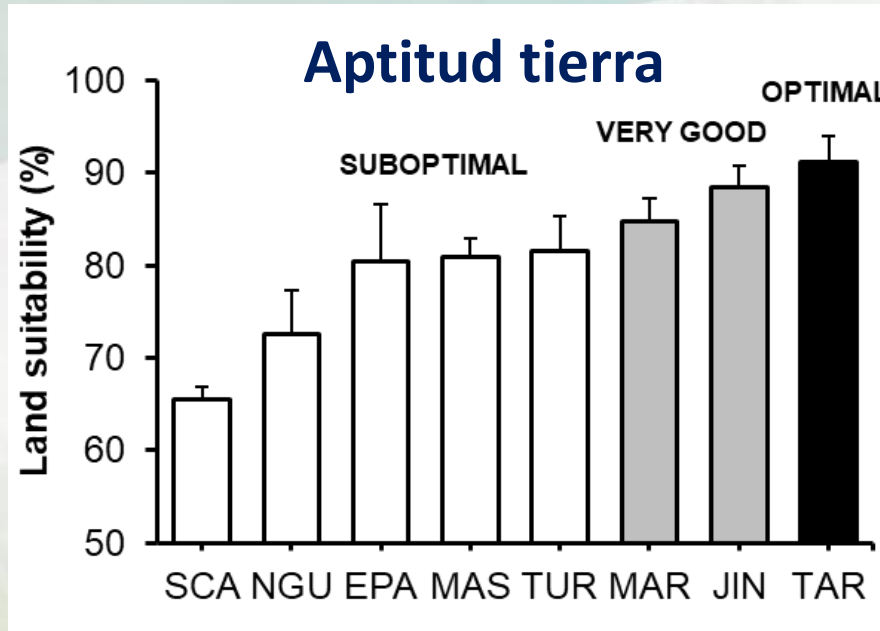
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Land suitability	
Category	Score (%)
Unsuitable	<60
Marginal	60 to 65
	65 to 70
	70 to 75
Moderate	75 to 80
	80 to 85
	85 to 90
Good	90 to 95
	95 to 100



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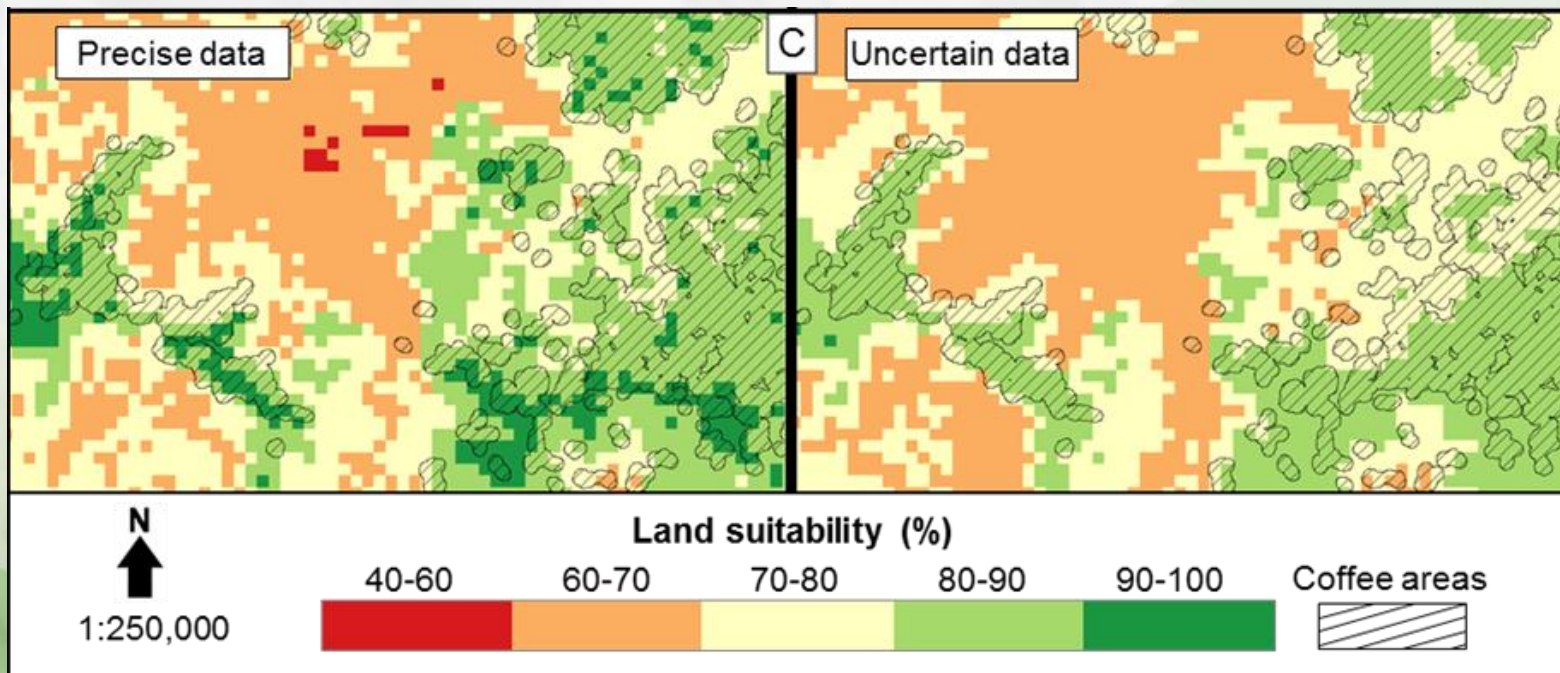
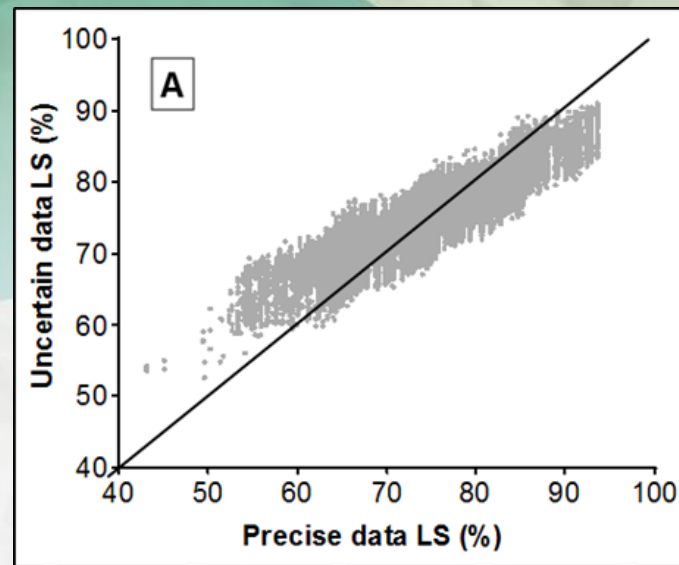
Evaluación de la tierra bajo incertidumbre



Evaluación bajo incertidumbre

Dataset con incertidumbre:

- pH, CIC, Temperatura, Precipitación
- *Distribuciones Gaussian*, intervalos, sets de (im)posibilidades, y otros





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Impacto del CC en la aptitud climática/tierra en Centroamérica



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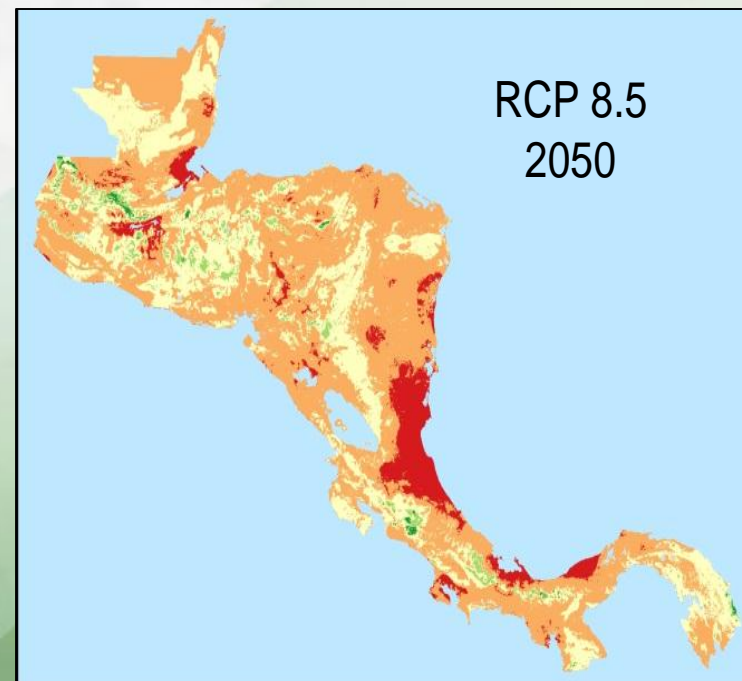
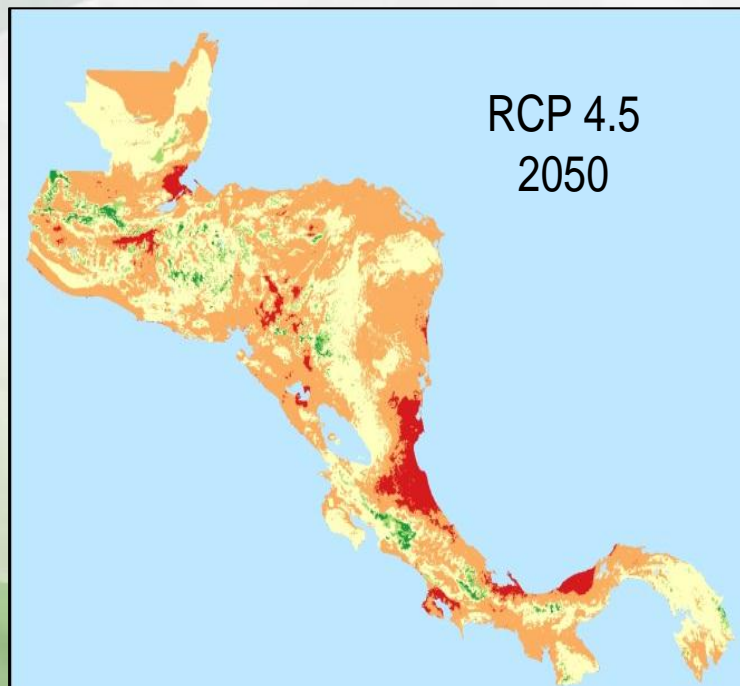
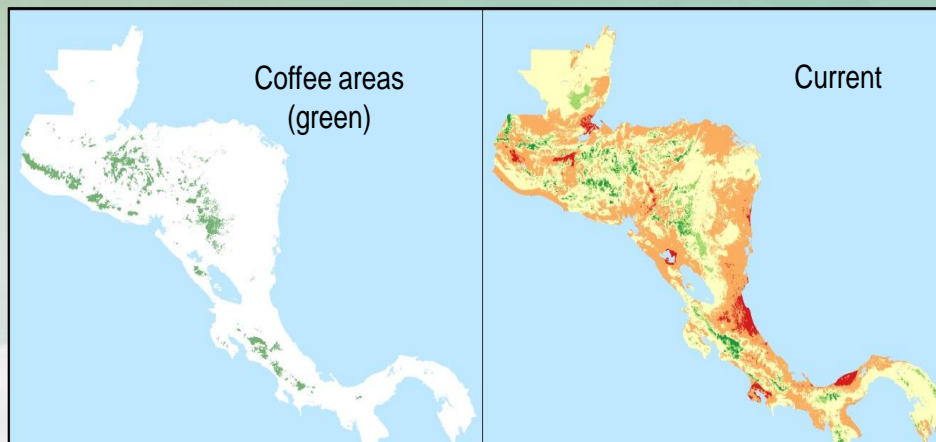
Impacto CC en aptitud climática/tierra

- Model ECHAM del Max Planck Institute (Fuentes-Franco et al., 2015; Maloney et al., 2013; Schaller et al., 2011).
- RCP 2.6, **4.5 y 8.5** para los años **2050** y 2080



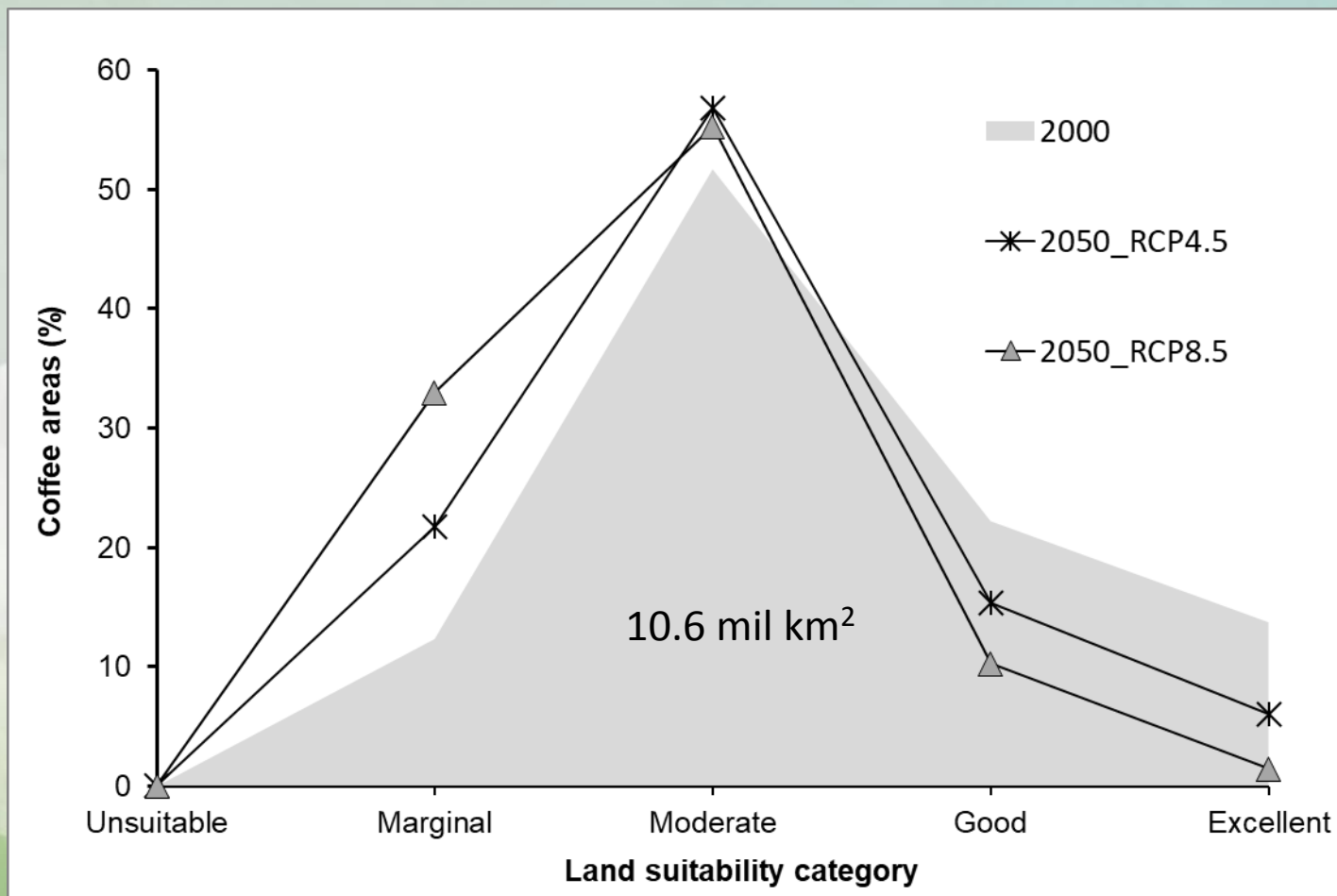
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Impacto CC en aptitud climática/tierra





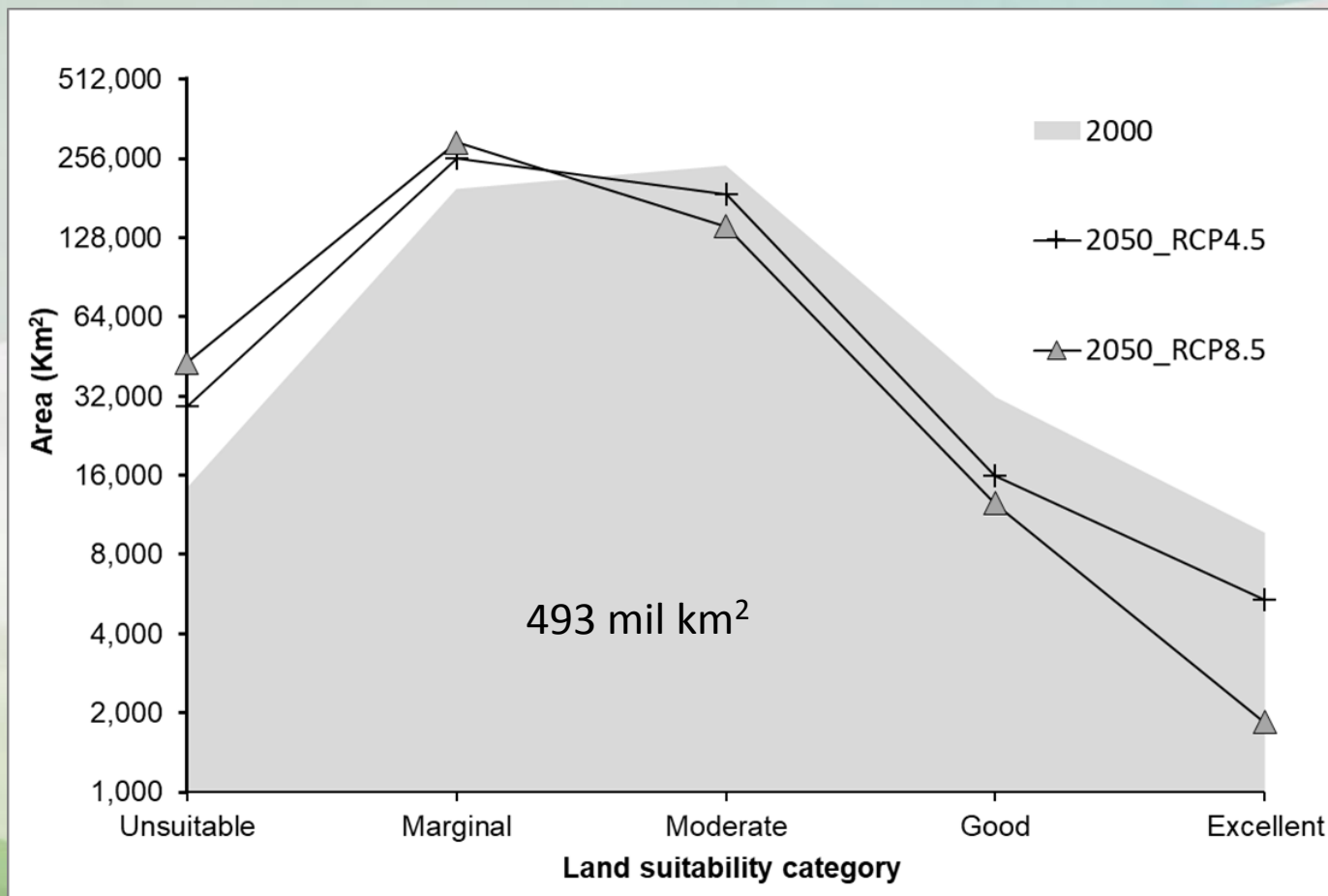
Áreas de café



Land suitability	
Category	Score (%)
Unsuitable	<60
	60 to 65
Marginal	65 to 70
	70 to 75
Moderate	75 to 80
	80 to 85
Good	85 to 90
	90 to 95
Excellent	95 to 100



Región (sin áreas de café)



Land suitability	
Category	Score (%)
Unsuitable	<60
	60 to 65
Marginal	65 to 70
	70 to 75
Moderate	75 to 80
	80 to 85
Good	85 to 90
	90 to 95
Excellent	95 to 100



RCP 4.5

- Reducción de las áreas buenas y excelentes (>80% aptitud) en un 12 a 55 % respec.
- Incremento: marginal y moderada (60 - 80% aptitud) desde un 47 a 214 % respec.

RCP 8.5

- Tendencias se acentúan: disminución del 90% de áreas clasificadas como excelentes.



CONCLUSIONES

1. ALECA capaz de evaluar la aptitud de la tierra (cierta/Incierta info.)
2. Áreas optimas actuales para café (>80% aptitud) se reducirán sensiblemente por efecto del CC
3. La evaluación de impactos de fenómenos como CC en la aptitud de la tierra para producir café (u otro cultivo) debe de considerar clima, suelo y relieve en su conjunto



CONCLUSIONES

4. Modelos gráficos como ALECA pueden ser utilizados como herramientas de consulta en la toma de decisiones durante procesos de planificación en el sector cafe



Siguientes pasos...

1. Utilizar ALECA para evaluar estrategias de adaptación/mitigación al cambio climático
2. Desarrollar interacciones entre variables/componentes
3. Ajustar el modelo a nivel varietal

School of Integrated Climate System Sciences

Un modelo probabilístico para explorar las alteraciones por el cambio climático en la aptitud climática de la tierra para la producción de café (*Coffea arabica* L.)

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