Generación de escenarios de cambio climático de alta resolución para aplicaciones en la toma de decisiones en agricultura

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A2C2
Adaptación de la Agricultura al Cambio Climático
Universidad de Talca

En Chile la variabilidad natural del clima genera cíclicamente eventos climáticos extremos, como inundaciones, tormentas severas, sequías, nevazones, granizadas y heladas. Estos eventos hacen que nuestro país sea considerado como vulnerable frente al cambio climático global, sin embargo, los gobiernos en Chile han fomentado estudios que nos ayuden a enfrentar con éxito la posibilidad de enfrentar impactos relevantes en la agricultura.

En términos generales, estudios locales, señalan una disminución de las precipitaciones y un aumento de la temperatura, sumado a cambios en la variabilidad climática. Estos cambios pueden generar peligros y riesgos que afectaran a la agricultura.

Uno de los principales problemas radica en la resolución de calculo a nivel espacial, por ejemplo 25 km, inadecuada para aplicarla en agricultura.

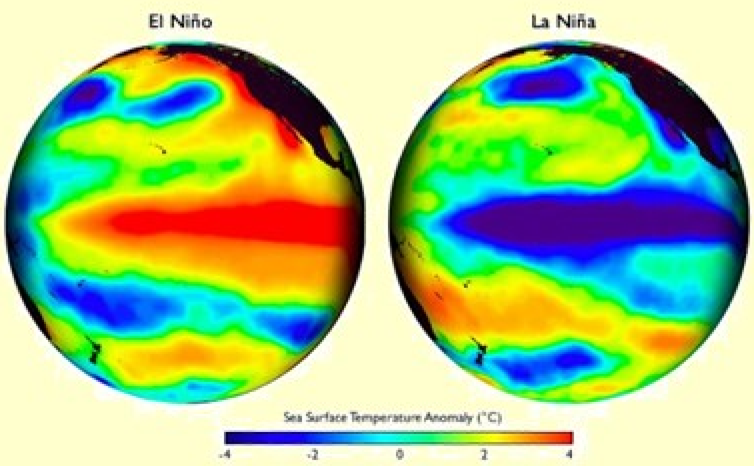
Producto de lo anterior, para realizar evaluaciones del impacto del cambio climático en la agricultura se requieren datos modelados espacialmente en alta resolución, por lo menos a 1 km.

Sin esta apropiada resolución es complejo que las evaluaciones realizadas a partir de ellos puedan convertirse en herramientas de planificación apropiadas para el sector agrícola, en especial al riego.

CLIMA

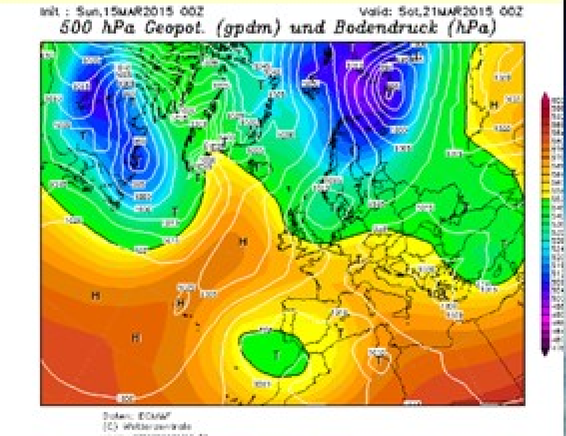
Variabilidad climática

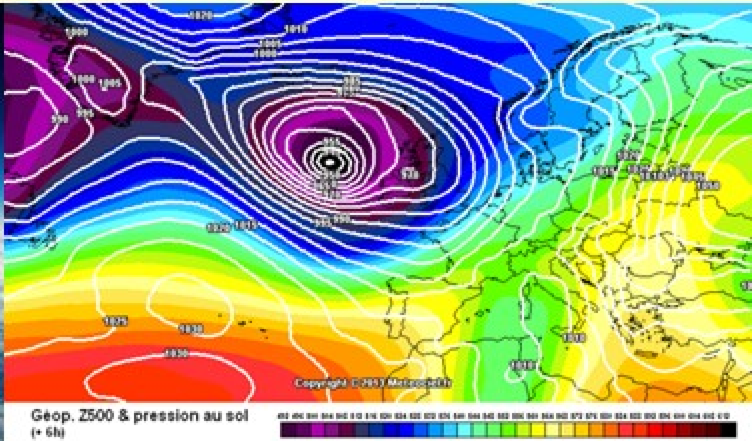
Cambio climático



Clima y Sector Agropecuario Colombiano
Adaptación para la Sostenibilidad Productiva

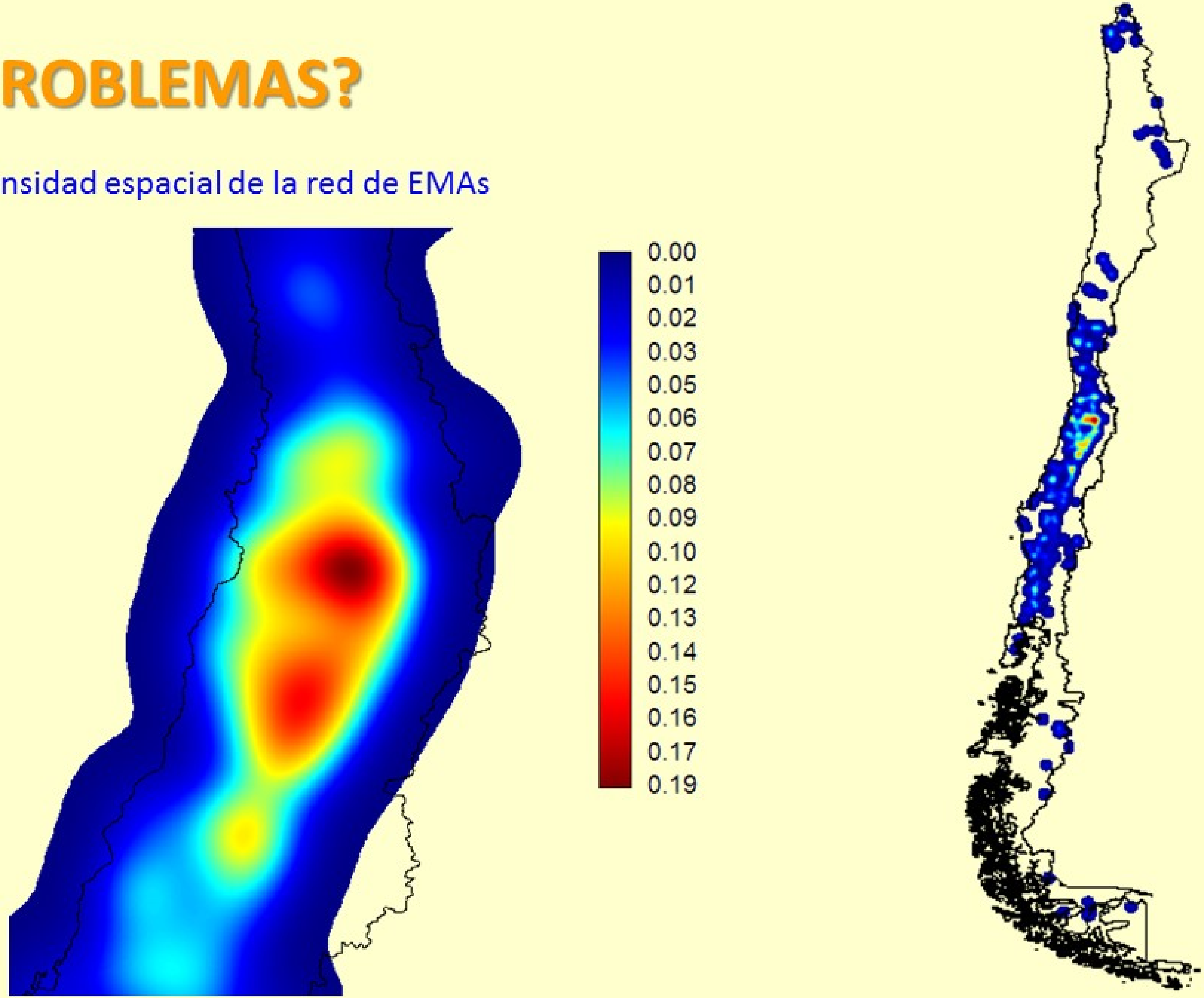
MODELOS DE CIRCULACION GENERAL DE LA ATMOSFERA (GCM)

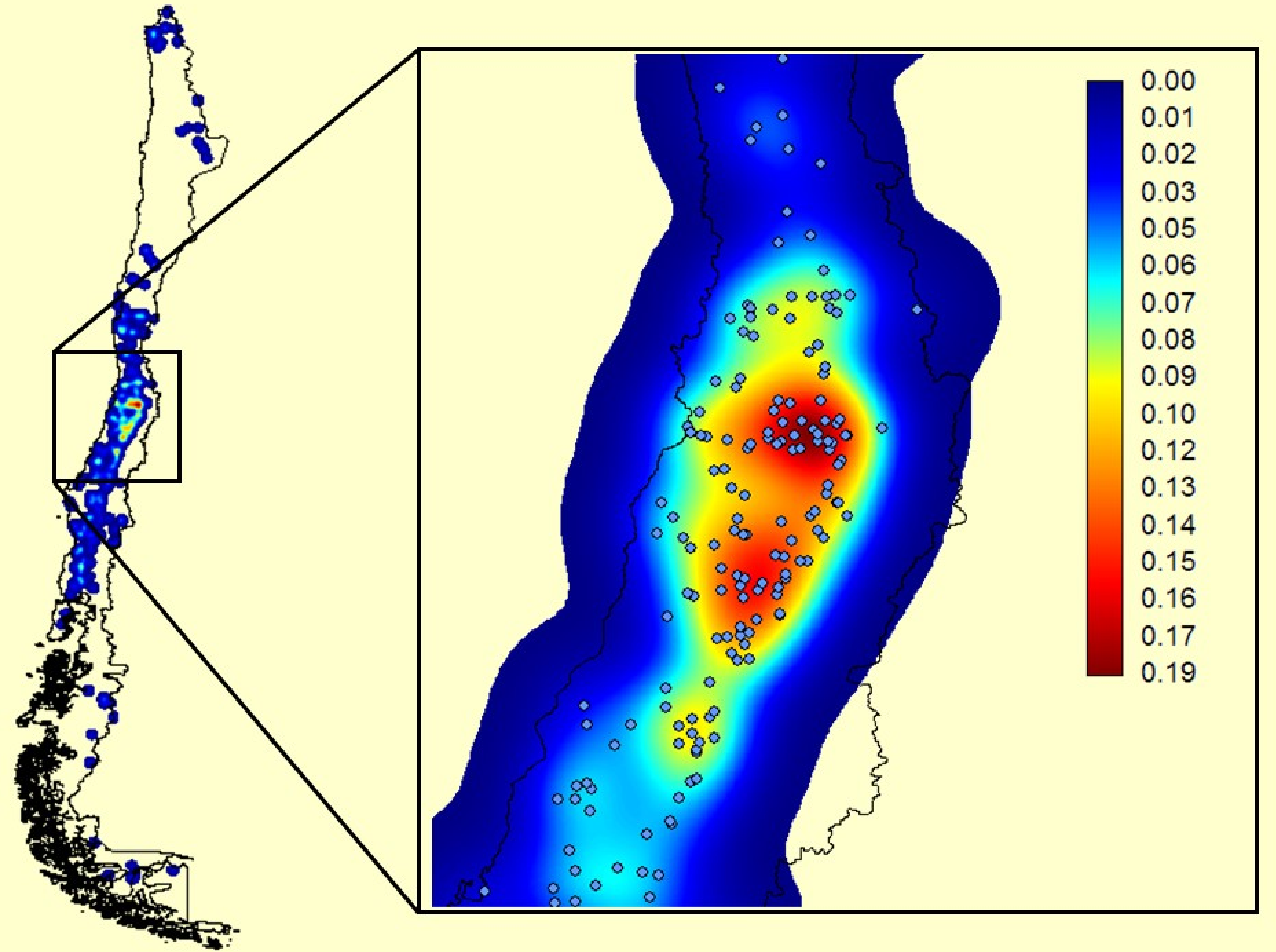




PROBLEMAS?

Densidad espacial de la red de EMAs




0.00
0.01
0.02
0.03
0.05
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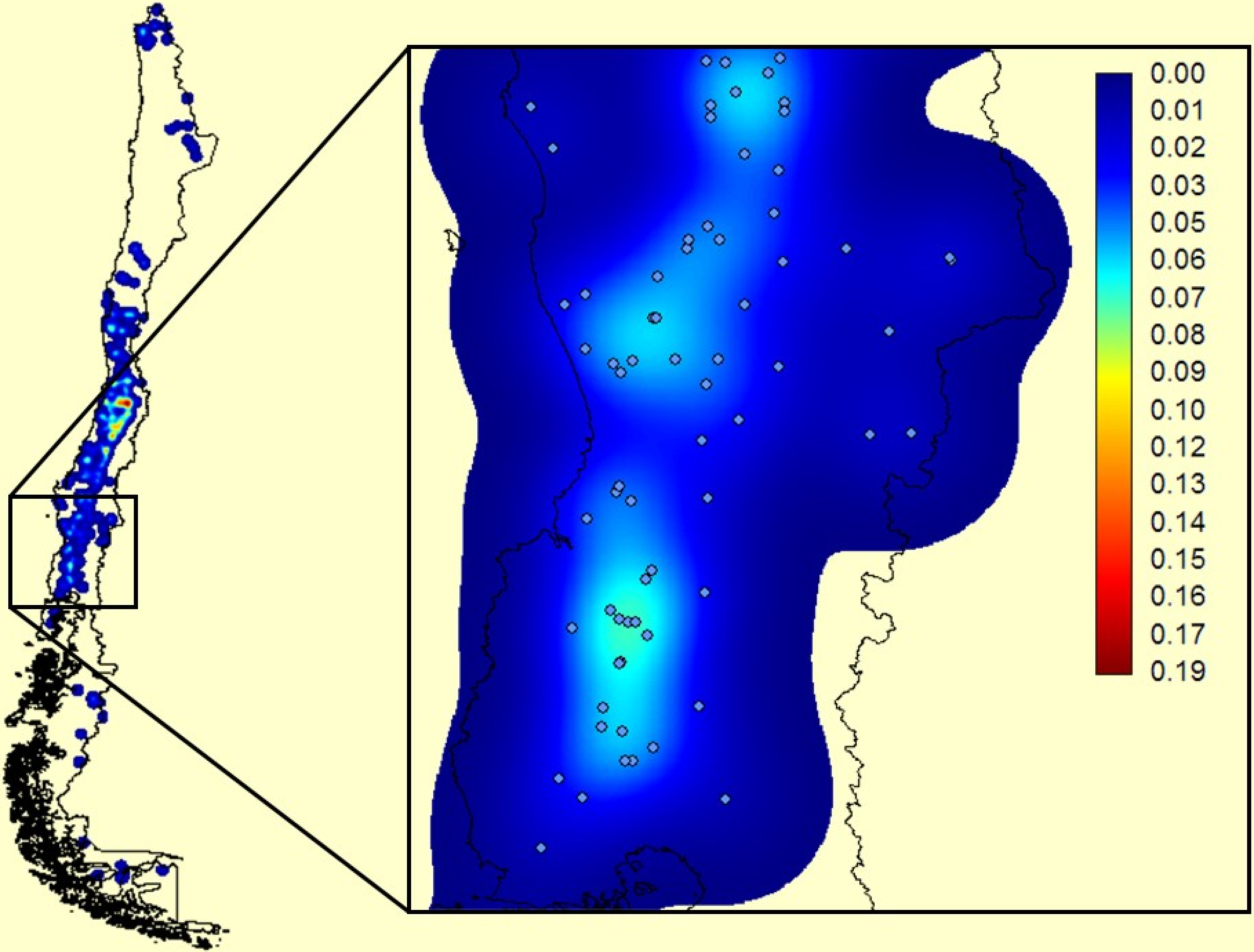
0.13
0.14
0.15
0.16
0.17
0.19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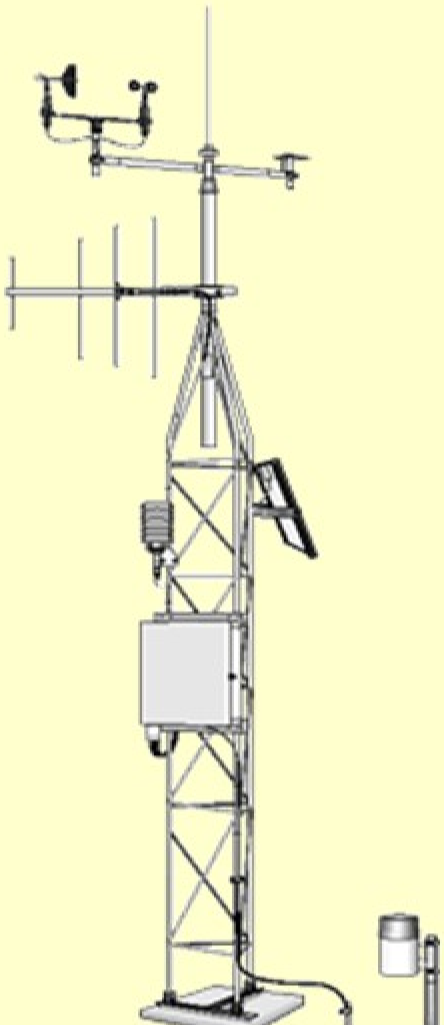
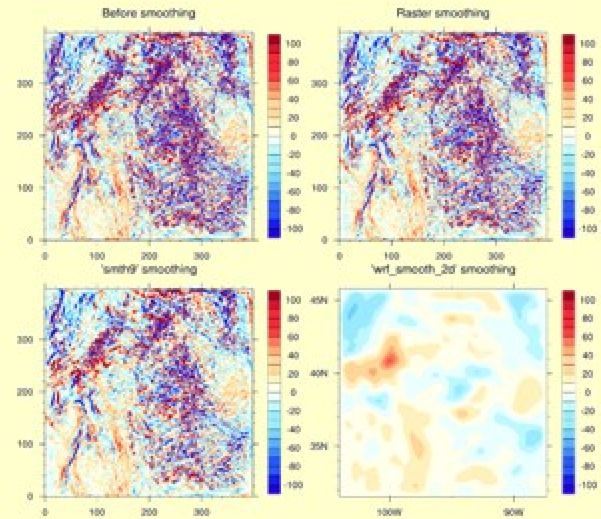
0.19

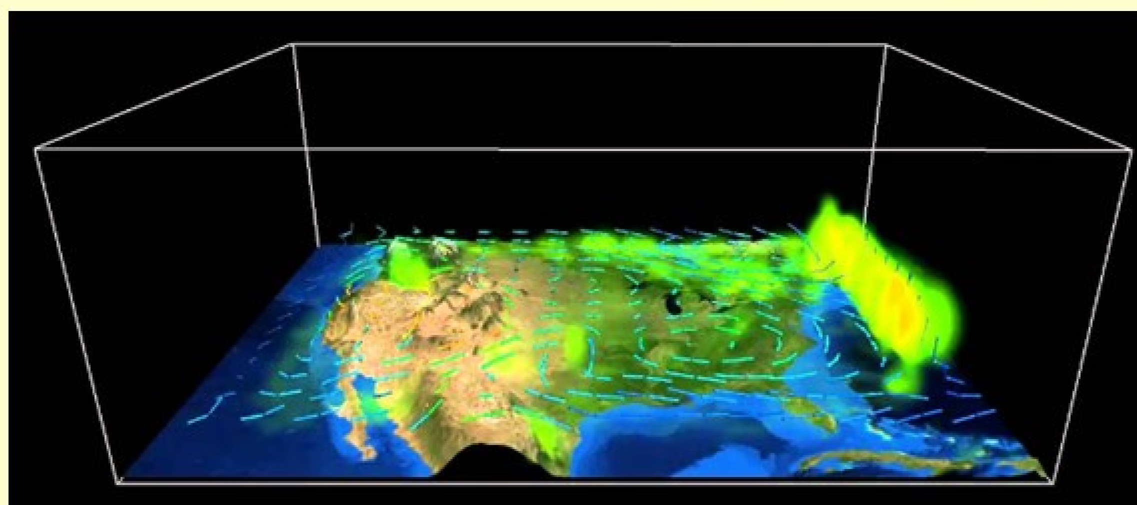
SOLUCION?

Modelación de mesoescala a partir de datos de EMAs, Teledetección y estadística espacial.



WRF
Weather Research & Forecasting

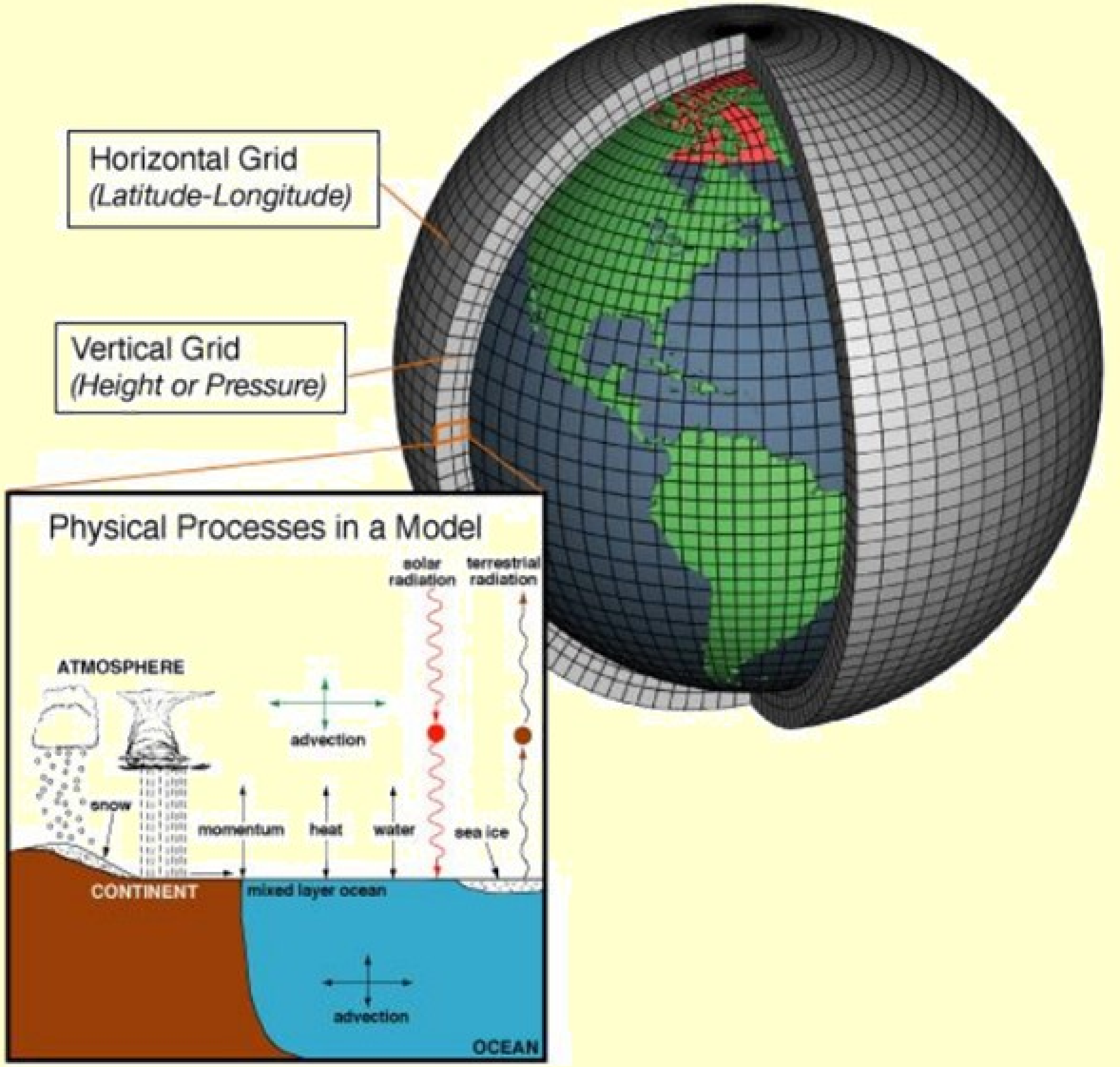




General or global circulation models (GCMs)

Simulan el clima de la tierra usando complejas ecuaciones matemáticas que describen la evolución de la atmósfera, océanos y todos los procesos bióticos derivados del funcionamiento de los ecosistemas y sus interacciones.

La salida matricial o GRID de estos modelos es gruesa.

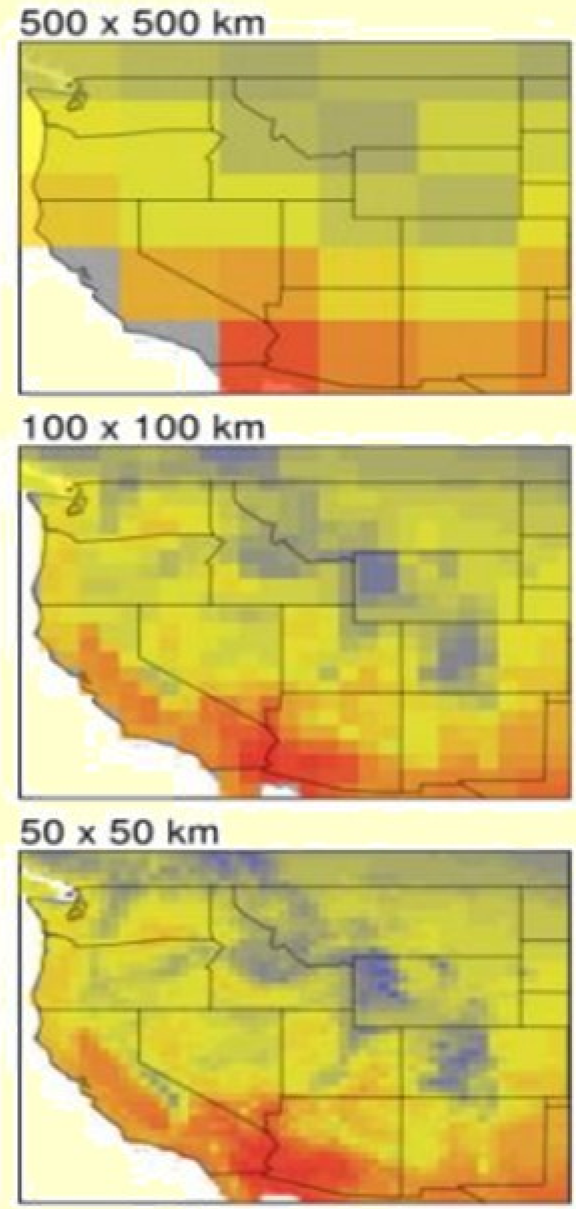


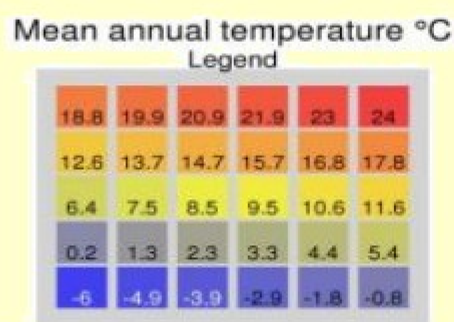
Temperatura media anual (1961–1990)

Esta figura muestra esta variable simulada por un GCM a una resolución espacial de *500 km, 100 km y 50 km.*

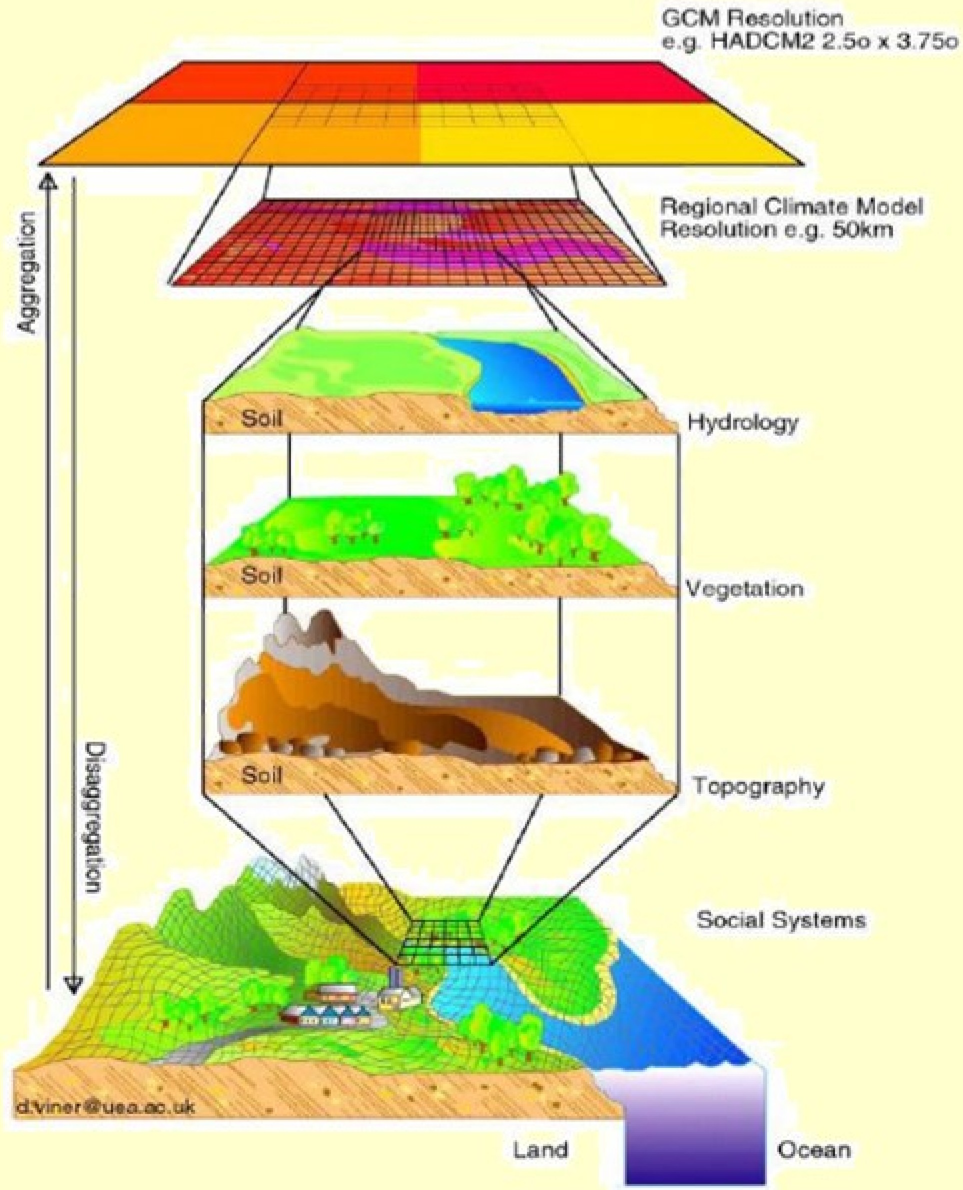
Para llevar estos GRIDS a resoluciones espaciales de la escala de los fenómenos que se observan y cuantifican en ecosistemas naturales y agrícolas hay que recurrir a un cambio de escala, llamado downscaling.

Daniels et al., 2012.

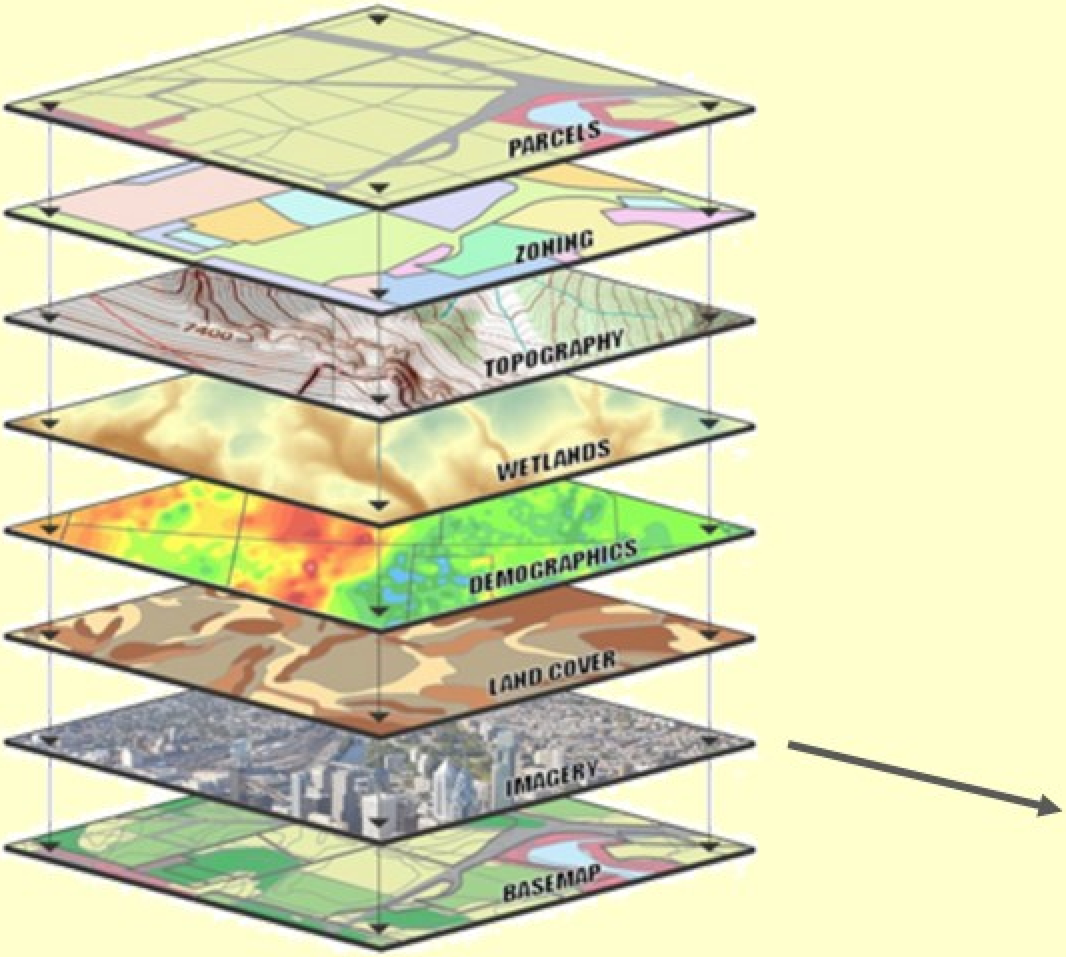


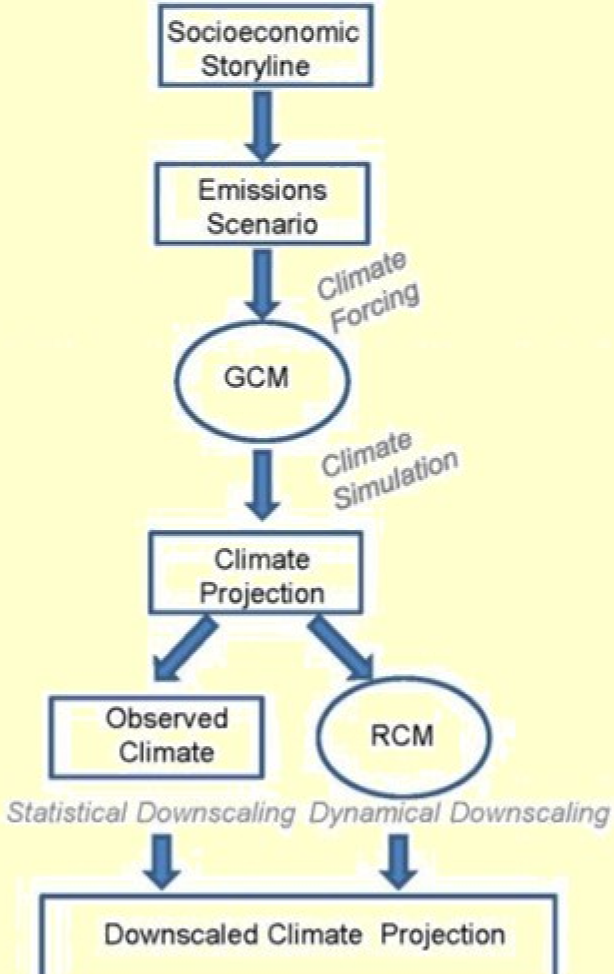


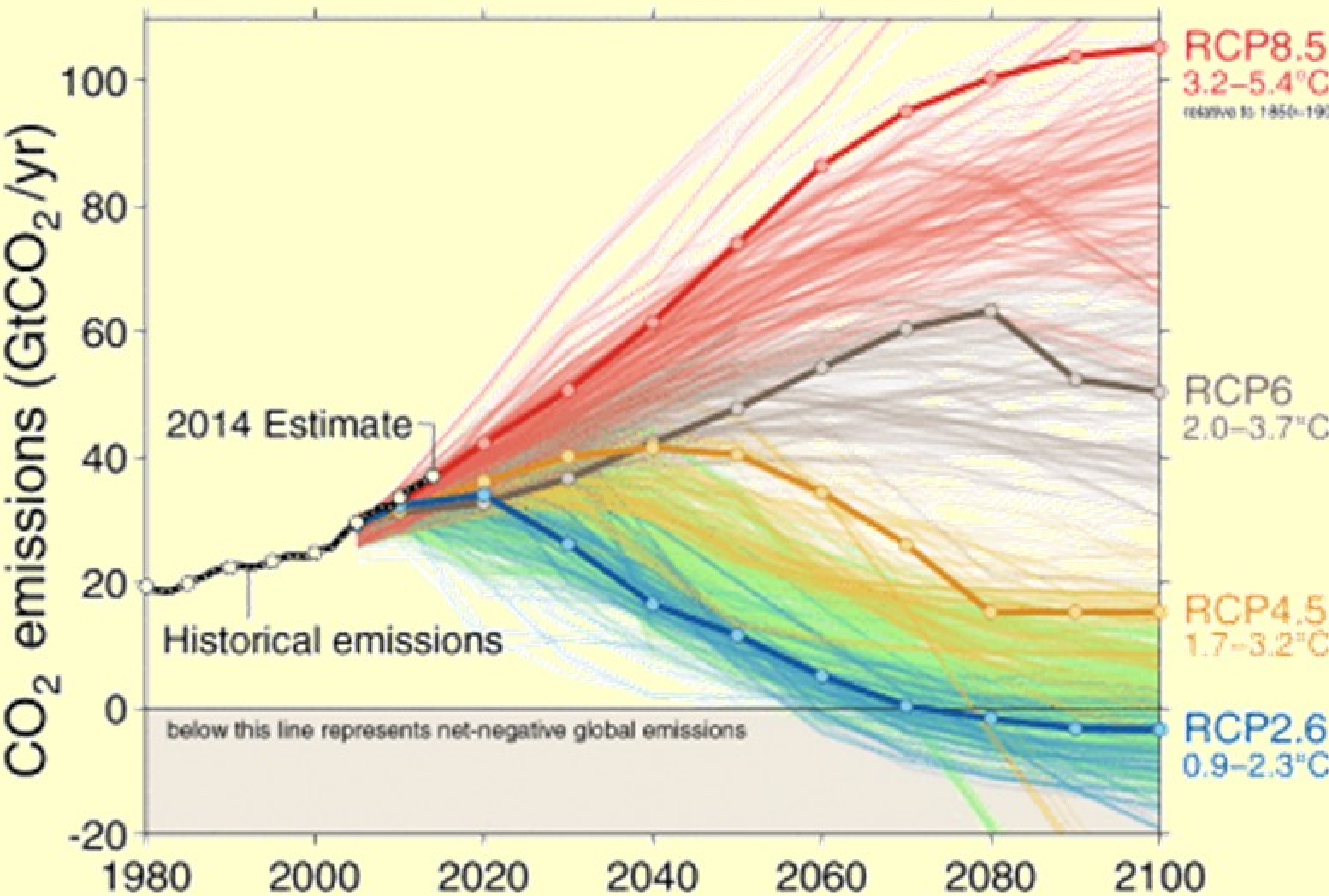
Muchos de los procesos que controlan el clima local, por ejemplo, topografía, la vegetación y la hidrología, no están incluidos GCM en baja resolución.



El desarrollo de relaciones estadísticas entre las escalas locales y regionales pueden incluir algunos de los procesos de mayor complejidad implícitamente

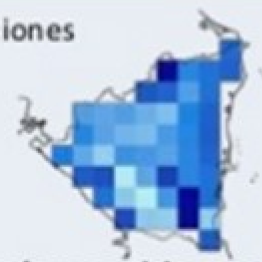






RCP8.5
3.2–5.4°C
relative to 1850–1900
RCP6
2.0–3.7°C
RCP4.5
1.7–3.2°C
RCP2.6
0.9–2.3°C
2014 Estimate
Historical emissions
below this line represents net-negative global emissions
CO_2 emissions ($GtCO_2$/yr)
100
80
60
40
20
0
-20
1980
2000
2020
2040
2060
2080
2100

Métodos Estadísticos v/s Dinámicos

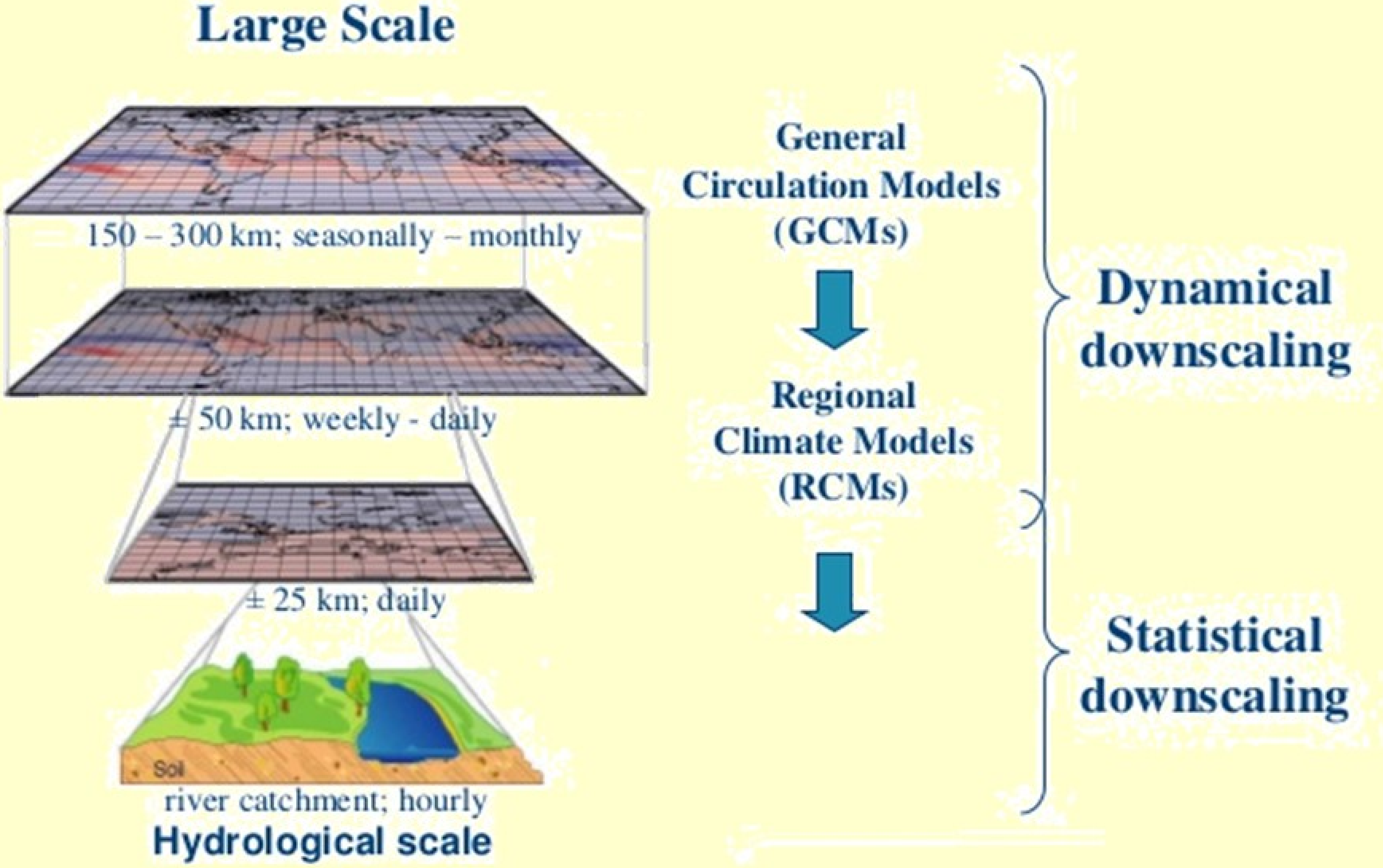
Método	Estadísticos	Dinámicos
Pros	↑ Resoluciones  ~ 1km - Rápido de implementar y más accequible - Aplicable a <u>TODOS</u> los GCMs	↑ Robusto ↑ Variables - Muy buenos para estudiar procesos atmosféricos - Aplicable a varios GCMs dependiendo de disponibilidad de datos
Contras	Cambios solo varían en gran escala ↓ variables	↓ Resoluciones  25-50 Km Requiere más experticia para correrlo Pocas plataformas, mucho procesamiento y almacenamiento Incertidumbre difíciles de cuantificar

CIAT

II

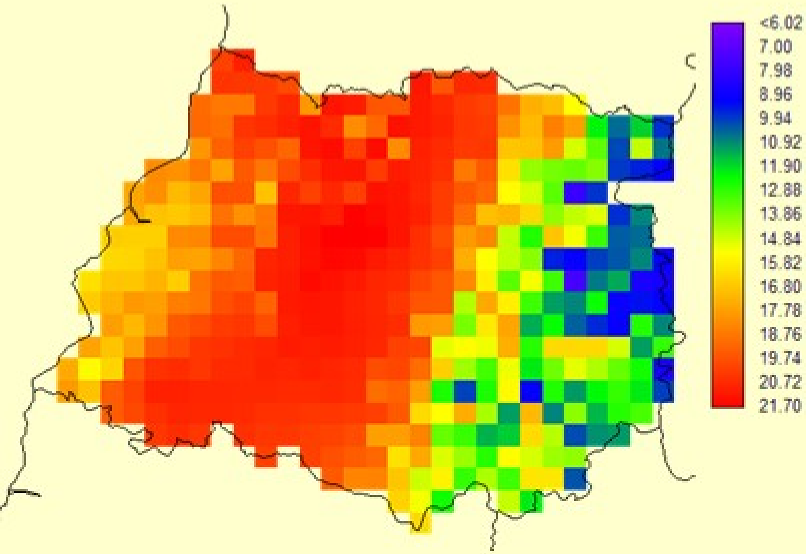
ESCENARIOS CLIMATICOS FUTUROS PARA LA AGRICULTURA



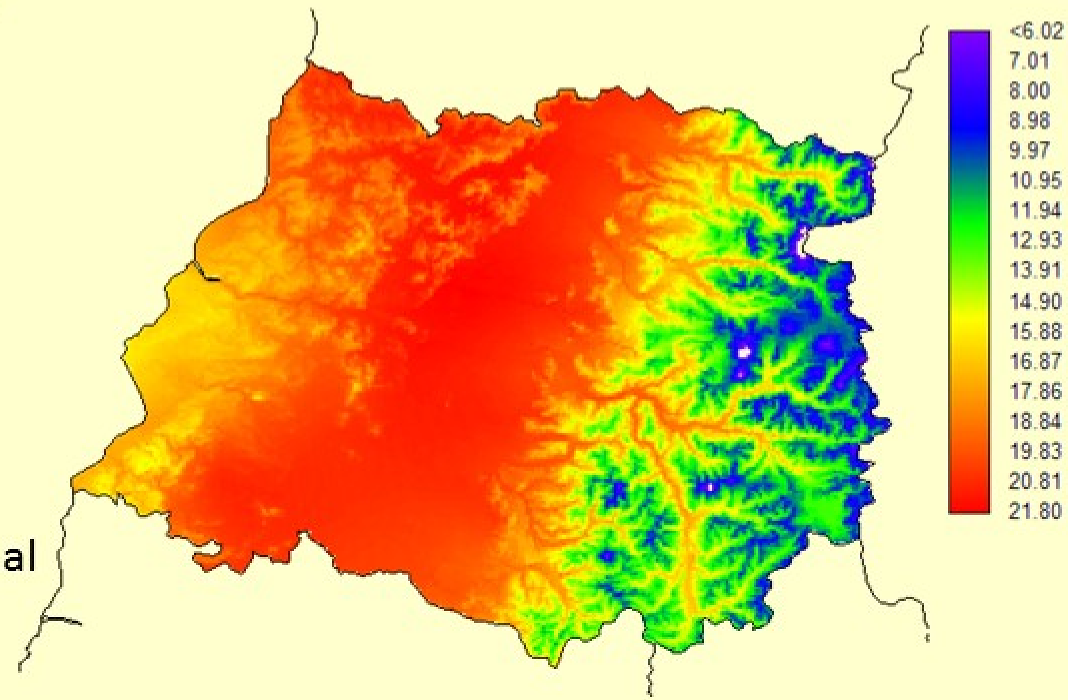



Large Scale
150 – 300 km; seasonally – monthly
± 50 km; weekly - daily
± 25 km; daily
Soil
river catchment; hourly
Hydrological scale
General Circulation Models (GCMs)
Regional Climate Models (RCMs)
Dynamical downscaling
Statistical downscaling

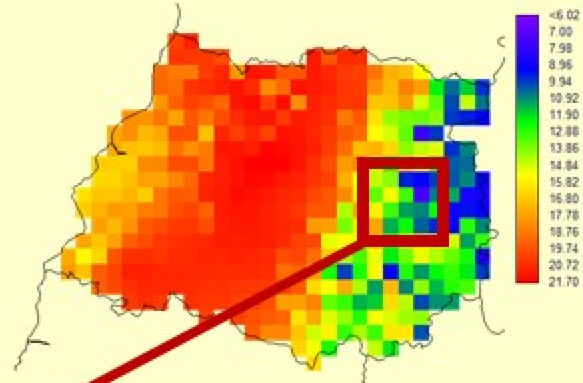
Concepto de Downscaling



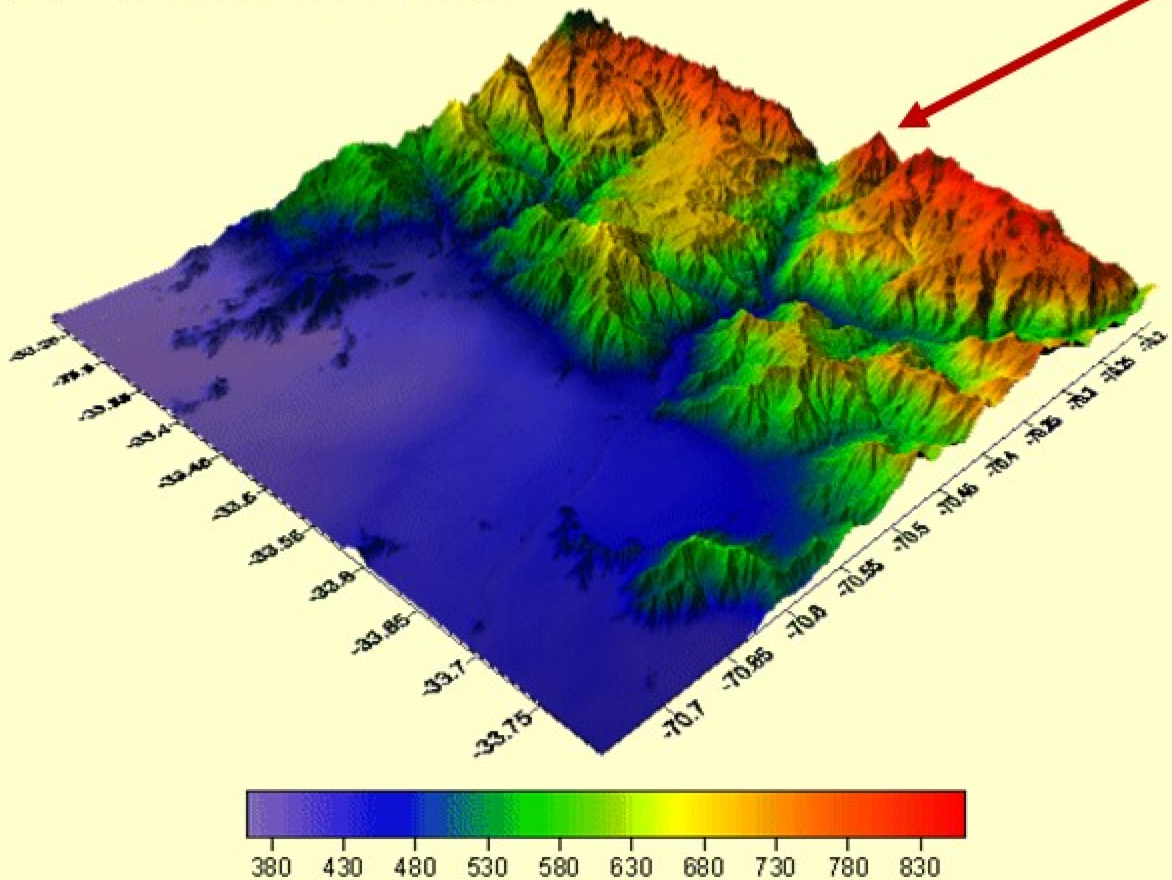
10 km resolución espacial

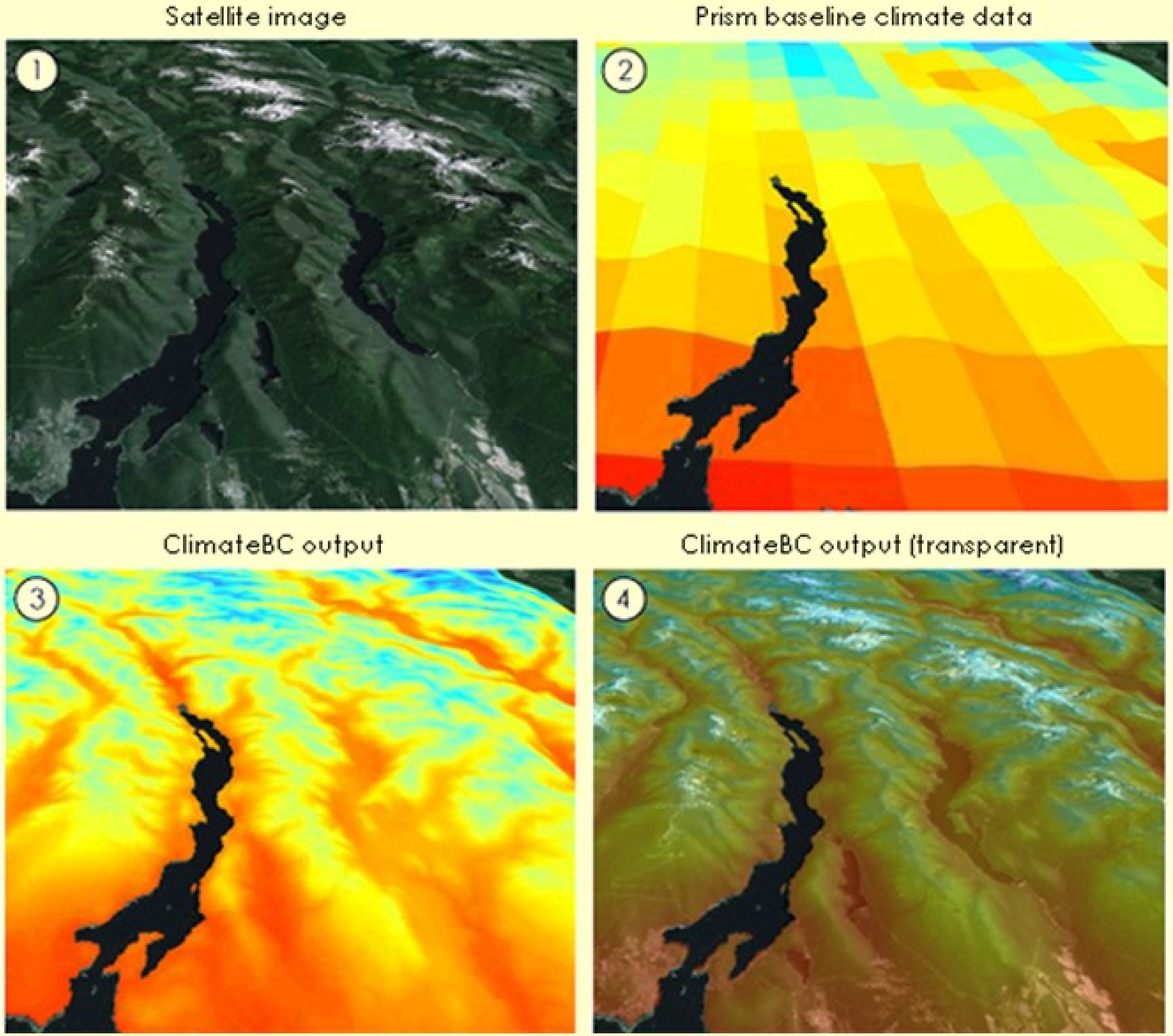


1 km resolución espacial



100 m resolución espacial

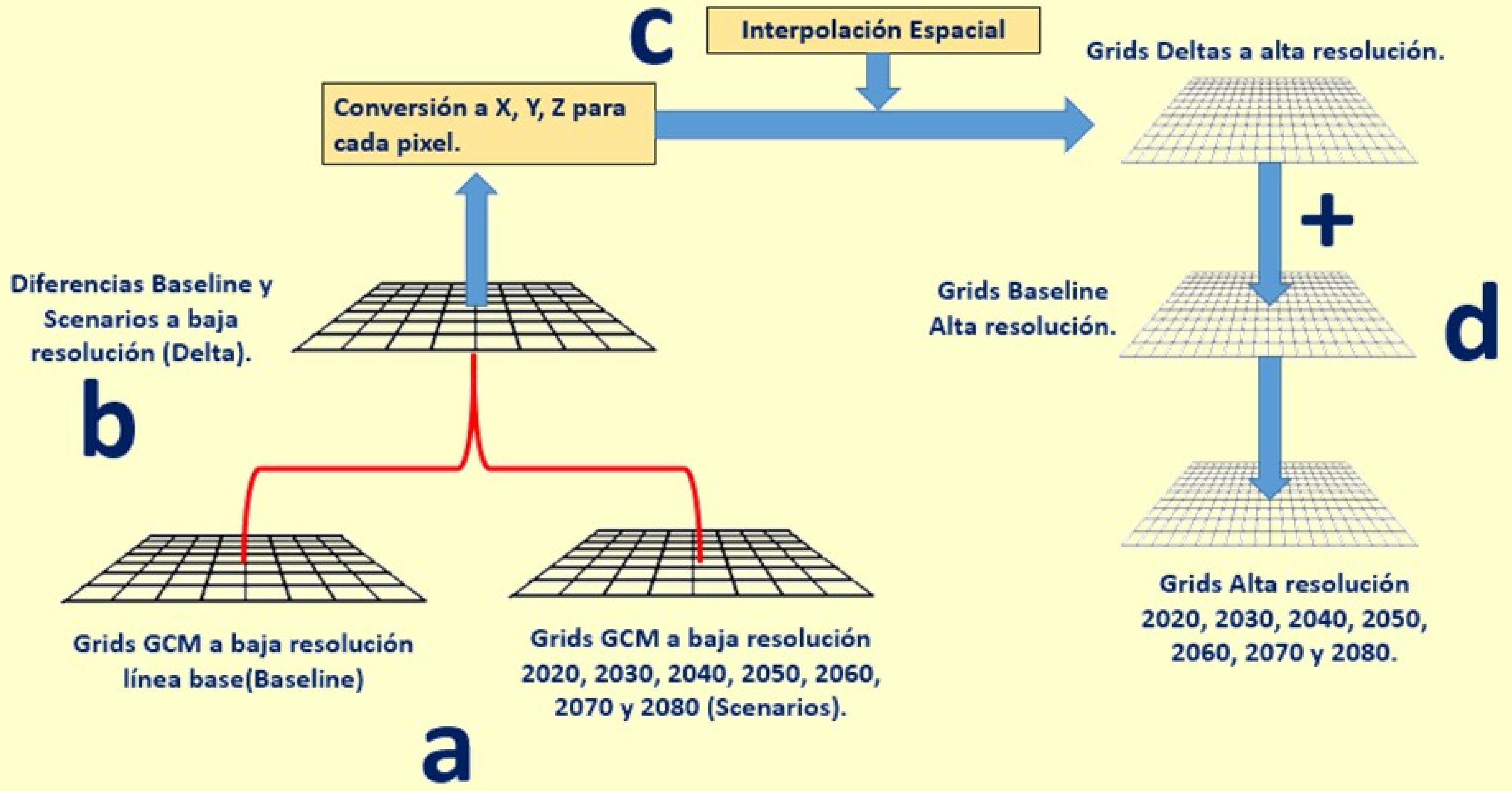




Wang, T., Hamann, A., Spittlehouse, D., and Murdock, T. N. 2012. ClimateWNA – High-resolution spatial climate data for western North America. Journal of Applied Meteorology and Climatology 61: 16-29.

Wang, T., Hamann, A., Spittlehouse, D., and Aitken, S. N. 2006. Development of scale-free climate data for western Canada for use in resource management..International Journal of Climatology 26: 383-397.

Statistical Downscaling: Delta Method



(Wilby et al., 2004; Ramirez y Jarvis, 2010; Anandhi et al., 2011)

a.- Bases de datos: Primeramente se debe contar con la base de datos climáticos tanto a nivel de línea base como a nivel de los escenarios generados por los modelos de circulación general de la atmósfera a la misma resolución espacial en ambos casos.

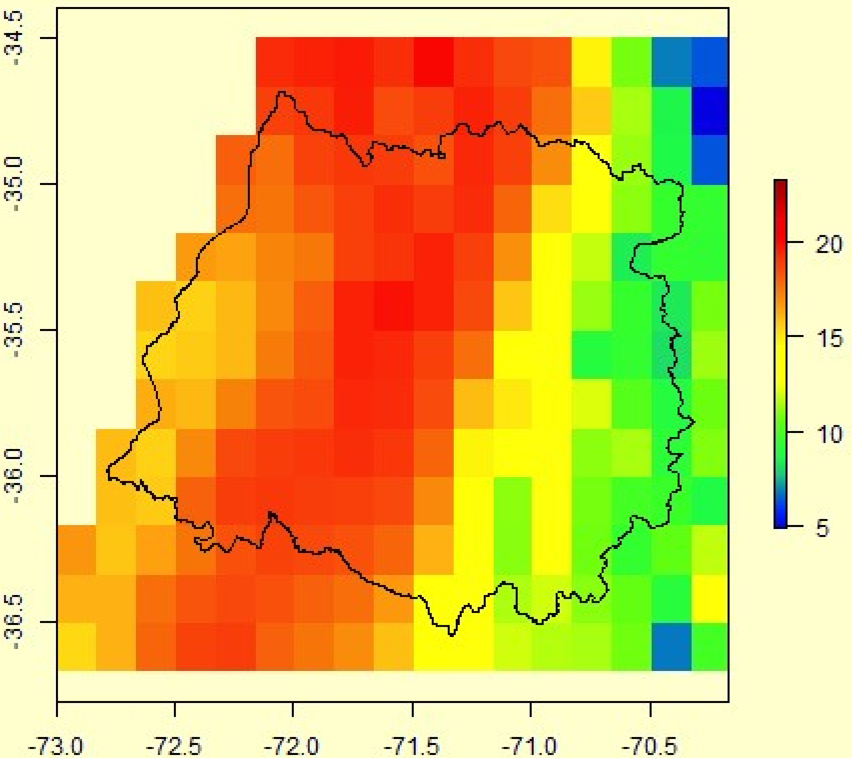
b.- Diferencias: En segundo lugar se deben calcular las diferencias o anomalías absolutas entre la línea base y cada uno de los escenarios generados por los modelos de circulación general de la atmósfera a la misma resolución espacial en ambos caso

$$\Delta X_{i,m} = X_{i,m}^{Baseline} - X_{i,m}^{Scenarios}$$

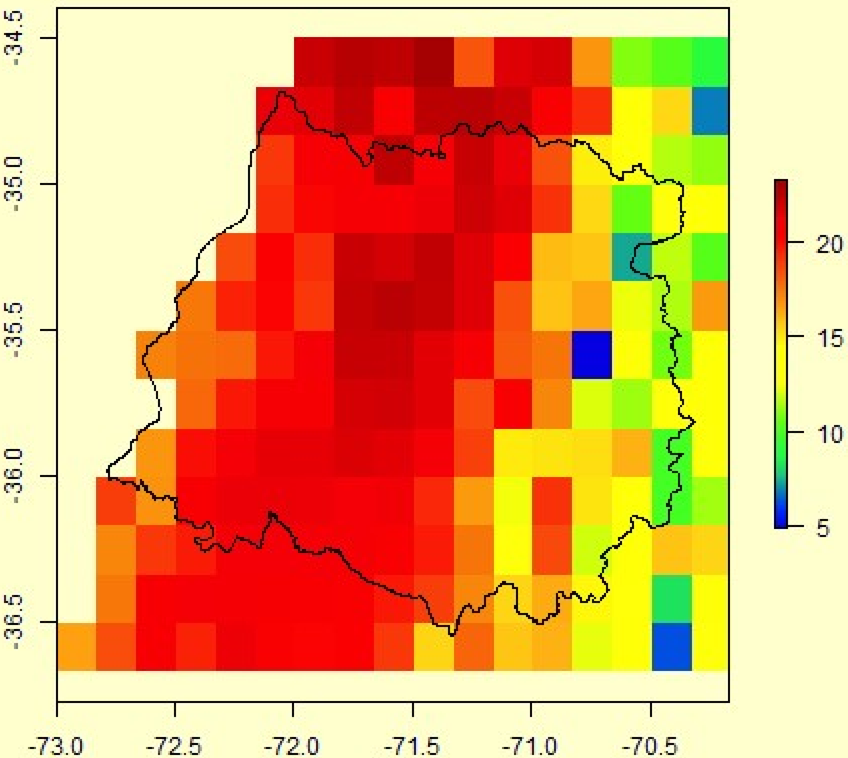
$\Delta X_{i,m}$: Es el valor calculado de Delta o anomalía.

$X_{i,m}^{Baseline}$: Es el valor de la variable correspondiente a la línea base.

$X_{i,m}^{Scenarios}$: Es el valor de la variable correspondiente al escenario considerado.

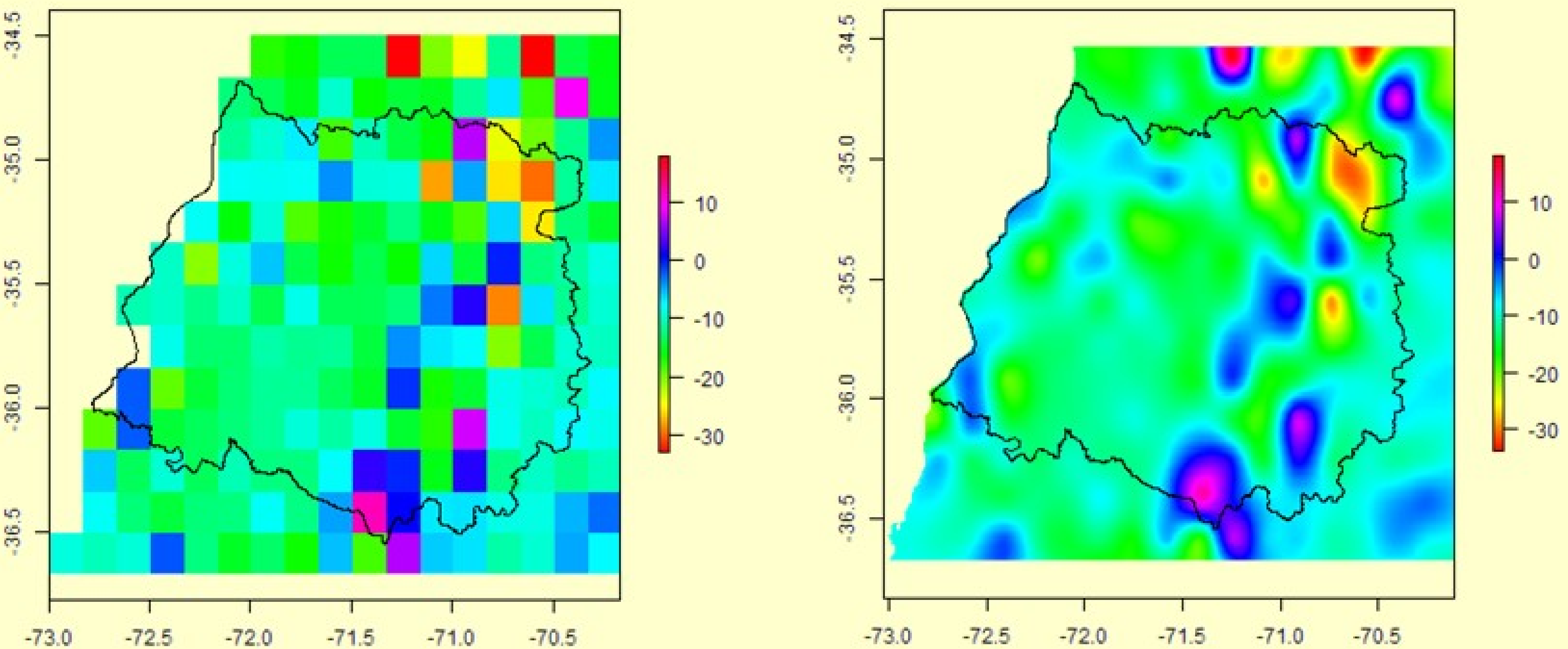


Baseline



2080

c.- Interpolación: Las diferencias calculadas en el paso anterior en formato grid se transforman en formato de texto con una estructura (X, Y, Z) para cada elemento o pixel de la matriz grid. Posteriormente cada delta de cada escenario contenido en el archivo de texto es interpolado usando kriging a la resolución espacial requerido (1 km) y trasformado nuevamente a formato grid. La figura 3 muestra, a modo de ejemplo, una reproducción de un informe de un proyecto similar al propuesto (Ramirez y Jarvis, 2010) de la interpolación realizada a diferencias entre la línea base y un escenario especifico.

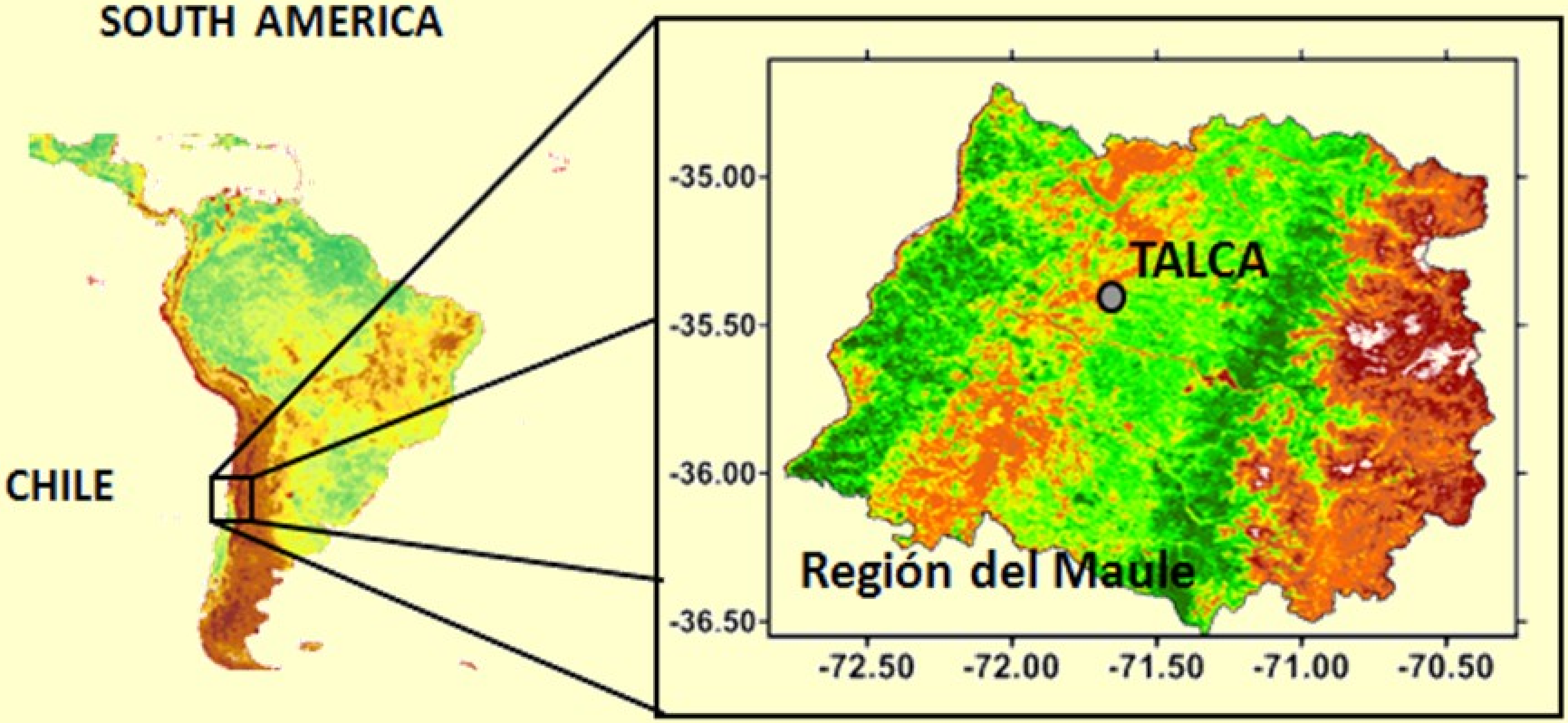


d.- Grids a alta resolución: Una vez que se han calculado las anomalías absolutas, estas deben ser sumadas a la línea base de la variable climatológica y mes correspondiente, de acuerdo a las ecuaciones siguientes.

$$X_{i,m} = X_{i,m}^{Baseline} + \Delta X_{i,m}$$

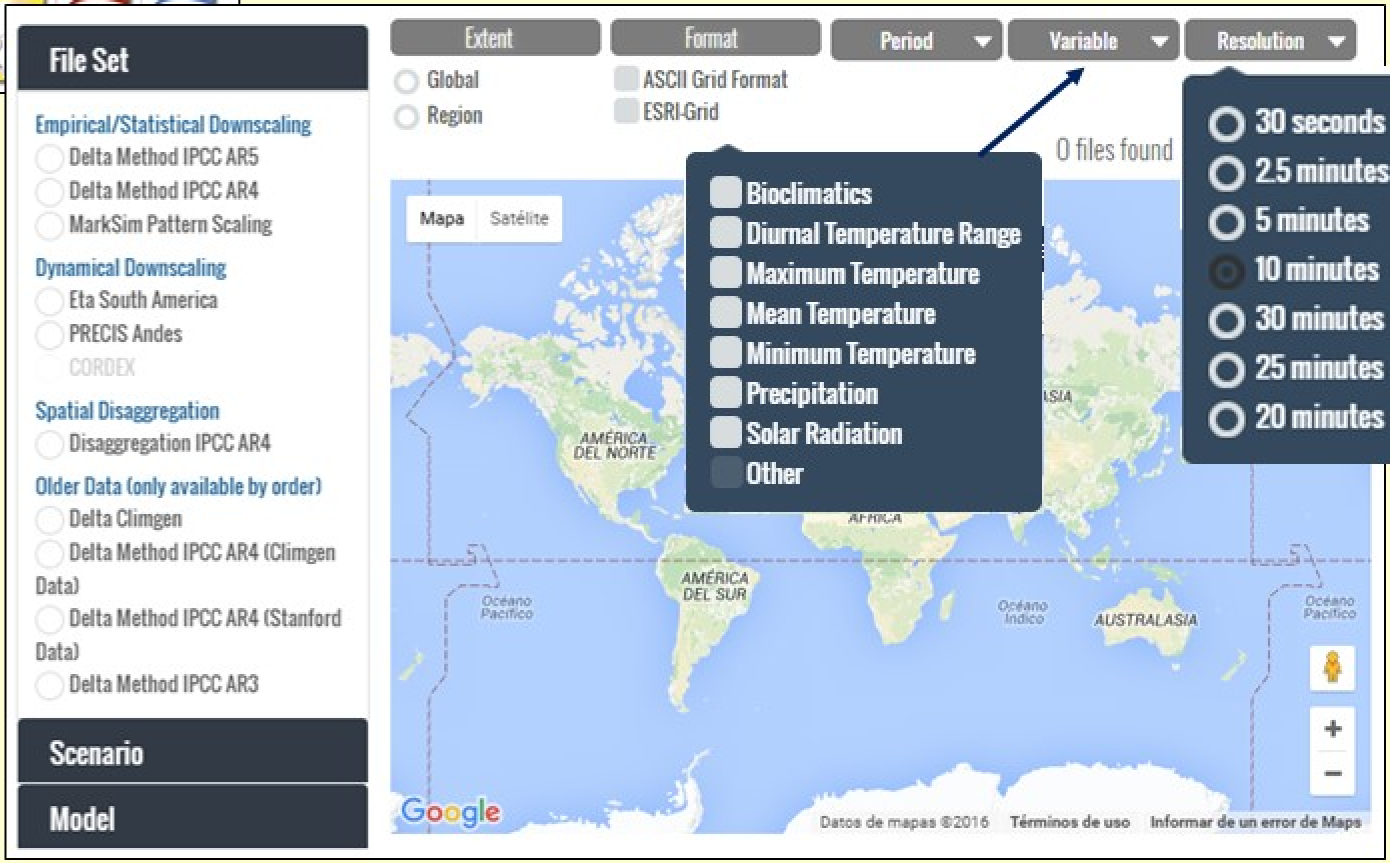
$$X_{i,m} = X_{i,m}^{Baseline} \cdot \left| 1 + \frac{\Delta X_{i,m}}{1 + X_{i,m}^{Baseline}} \right|$$

Área de Estudio



Base de datos GCM

http://www.ccafs-climate.org/

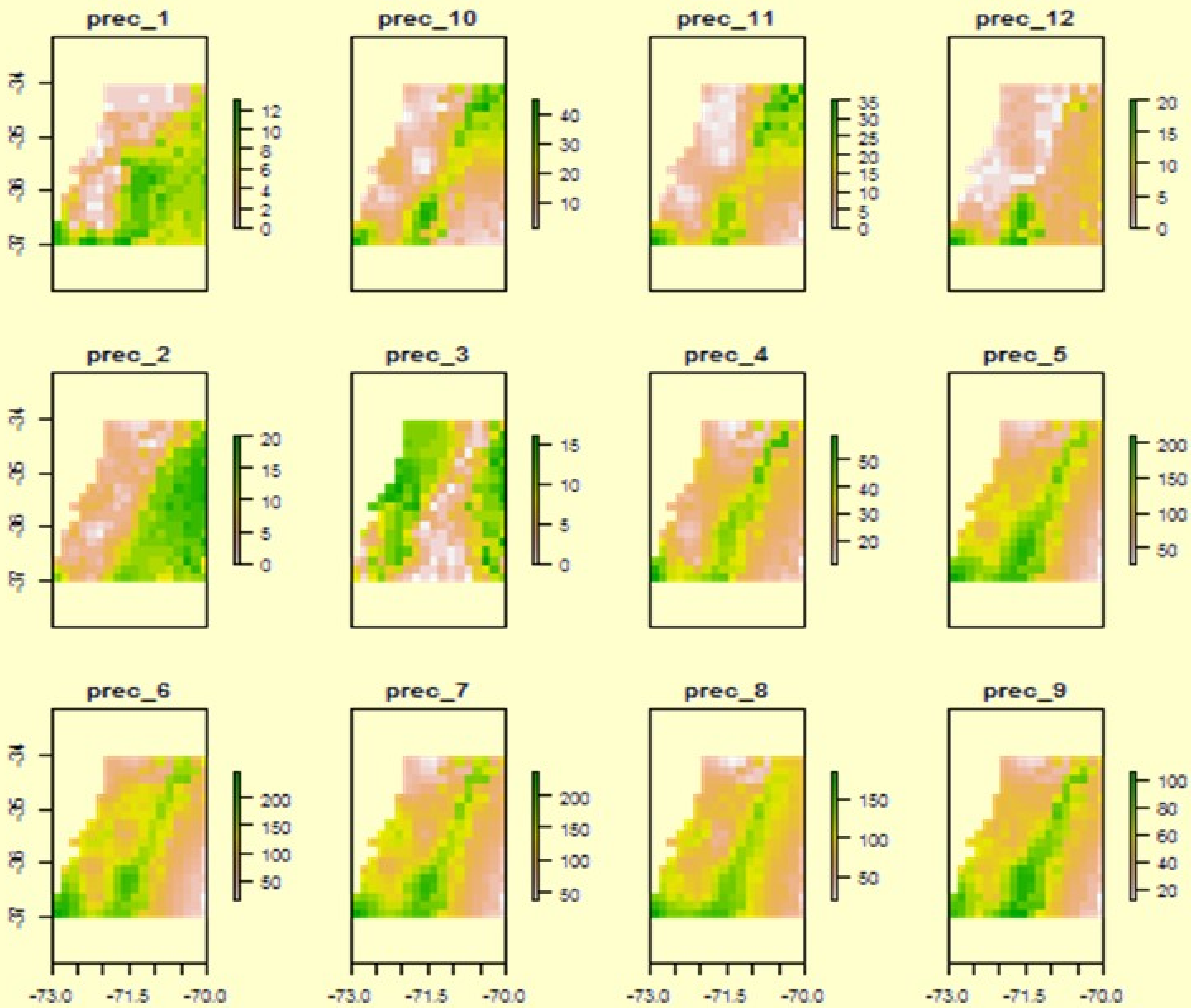


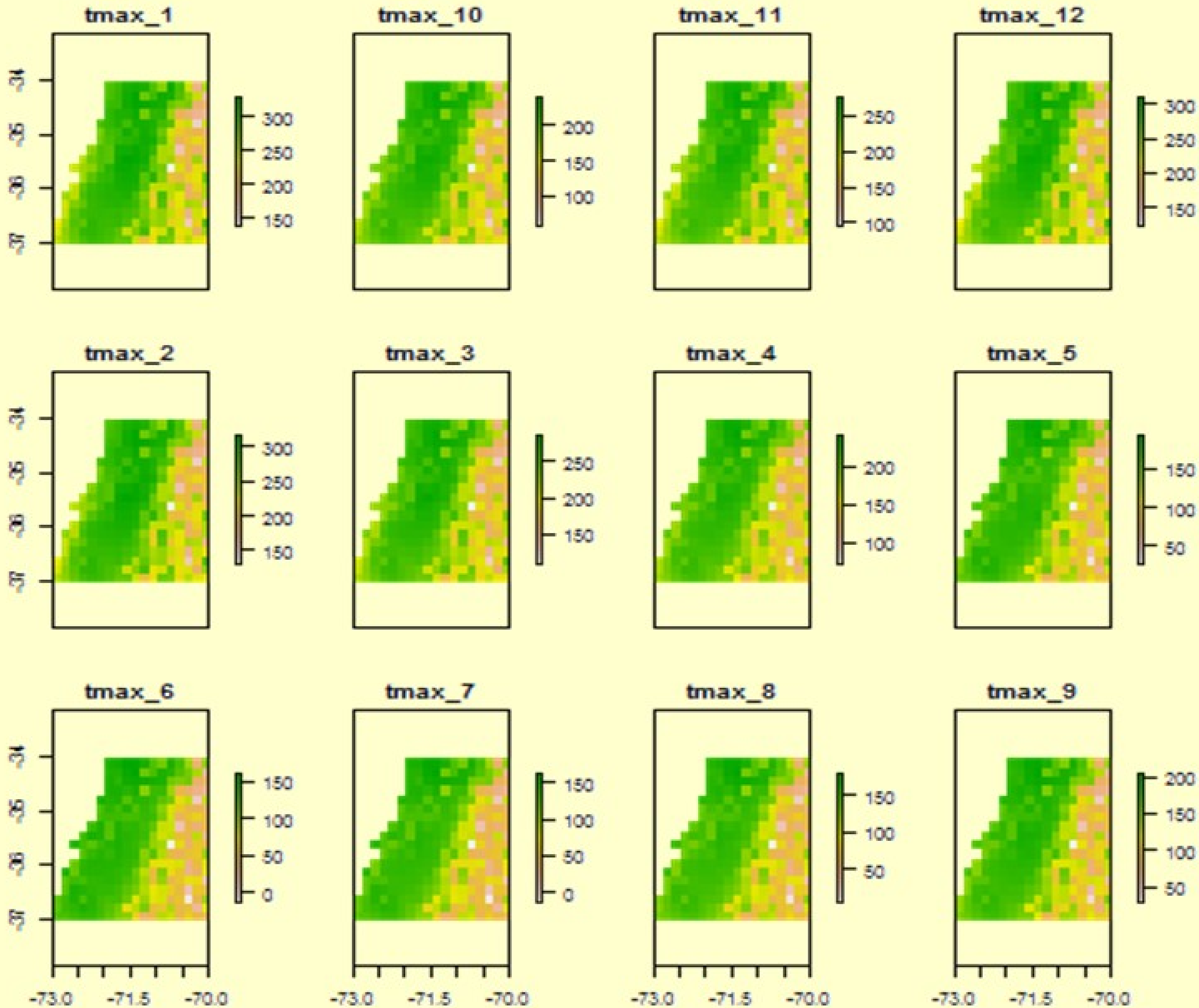
Modelos GCM disponibles y sus principales características (País de origen, resolución y referencia bibliográfica)

Modelo	País	Atmósfera	Océano	Referencia
BCCR-BCM2.0	Norway	T63,L31	1.5x0.5,L35	N/A
CCCMA-CGCM3.1(T47)	Canada	T47(3.75x3.75),L31	1.85x1.85,L29	Scinocca et al. (2008)
CCCMA-CGCM3.1(T63)	Canada	T63(2.8x2.8),L31	1.4x0.94,L29	Scinocca et al. (2008)
CNRM-CM3	France	T63(2.8x2.8),L45	1.875x(0.5-2),L31	Salas-Mélia et al. (2005)
CSIRO-Mk3.0	Australia	T63,L18	1.875x0.84,L31	Gordon et al. (2002)
CSIRO-Mk3.5	Australia	T63,L18	1.875x0.84,L31	Gordon et al. (2002)
GFDL-CM2.0	USA	2.5x2.0,L24	1.0x(1/3-1),L50	Delworth et al. (2004)
GFDL-CM2.1	USA	2.5x2.0,L24	1.0x(1/3-1),L50	Delworth et al. (2004)
GISS-AOM	USA	4x3,L12	4x3,L16	Russell et al. (1995)
GISS-MODEL-EH	USA	5x4,L20	5x4,L13	Schmidt et al. (2005)
GISS-MODEL-ER	USA	5x4,L20	5x4,L13	Schmidt et al. (2005)
IAP-FGOALS1.0-G	China	2.8x2.8,L26	1x1,L16	Yu et al. (2004)
INGV-ECHAM4	Italy	T42,L19	2x(0.5-2),L31	Gualdi et al. (2006)
INM-CM3.0	Russia	5x4,L21	2.5x2,L33	Diansky et al. (2002)
IPSL-CM4	France	2.5x3.75,L19	2x(1-2),L30	Marti et al. (2005)
MIROC3.2-HIRES	Japan	T106,L56	0.28x0.19,L47	Hasumi and Emori (2004)
MIROC3.2-MEDRES	Japan	T42,L20	1.4x(0.5-1.4),L43	Hasumi and Emori (2004)
MIUB-ECHO-G	Germany/Korea	T30,L19	T42,L20	Grötzner et al. (1996)
MPI-ECHAM5	Germany	T63,L32	1x1,L41	Jungclaus et al. (2005)
MRI-CGCM2.3.2A	Japan	T42,L30	2.5x(0.5-2.0)	Yukimoto et al. (2001)
NCAR-CCSM3.0	USA	T85L26,1.4x1.4	1x(0.27-1),L40	Collins et al. (2005)
NCAR-PCM1	USA	T42(2.8x2.8),L18	1x(0.27-1),L40	Washington et al. (2000)
UKMO-HADCM3	UK	3.75x2.5,L19	1.25x1.25,L20	Gordon et al. (2002)
UKMO-HADGEM1	UK	1.875x1.25,L38	1.25x1.25,L20	Johns et al. (2006)

La línea base fue obtenida como el promedio de los datos climatológicos de 30 años, la cual se encuentra centrada entre los años 1961 al 1990, según el método propuesto por la WMO. En cambio los escenarios del cambio climático son para cada década fue calculada como una media móvil centrada en una década específica, de acuerdo a

Década	Promedio móvil
1.	2010-2039, referido al 2020
2.	2020-2049, referido al 2030
3.	2030-2059, referido al 2040
4.	2040-2069, referido al 2050
5.	2050-2079, referido al 2060
6.	2060-2089, referido al 2070
7.	2070-2099, referido al 2080


prec_1
prec_10
prec_11
prec_12
prec_2
prec_3
prec_4
prec_5
prec_6
prec_7
prec_8
prec_9
-34
-35
-36
-37
-73.0
-71.5
-70.0



tmax_1
tmax_10
tmax_11
tmax_12
tmax_2
tmax_3
tmax_4
tmax_5
tmax_6
tmax_7
tmax_8
tmax_9
-73.0
-71.5
-70.0

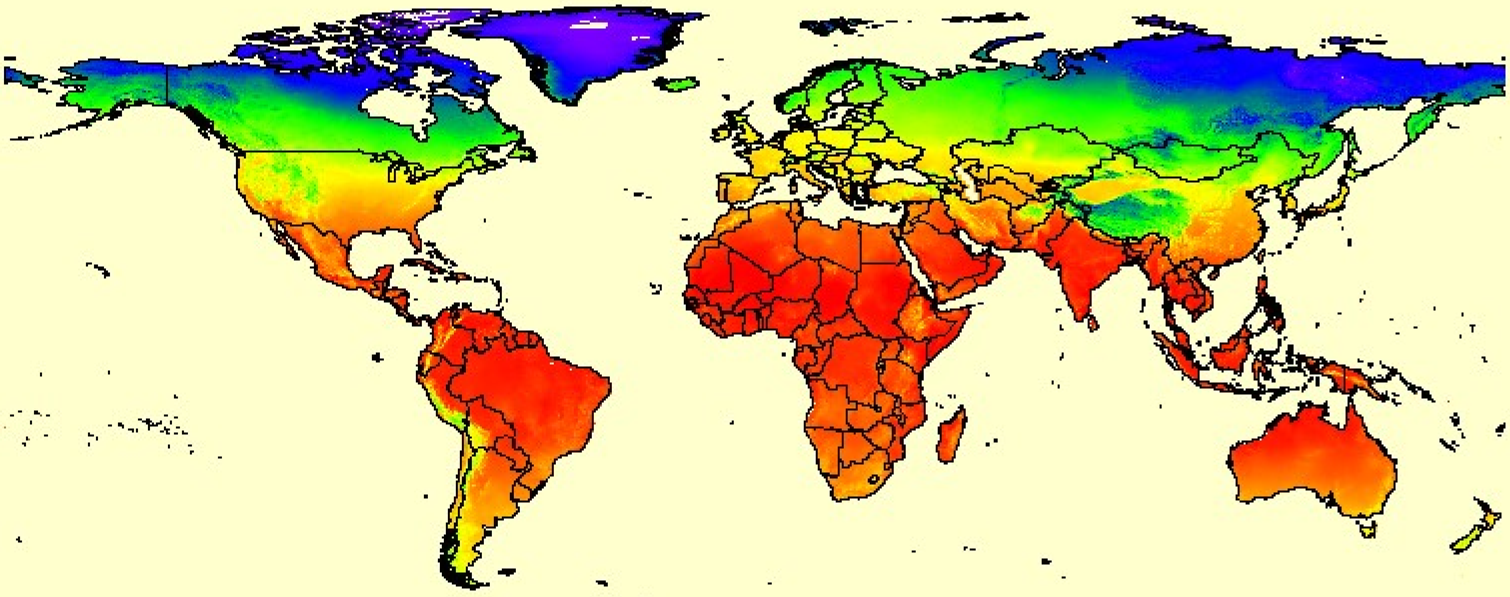
Línea Base: WORLDCLIM

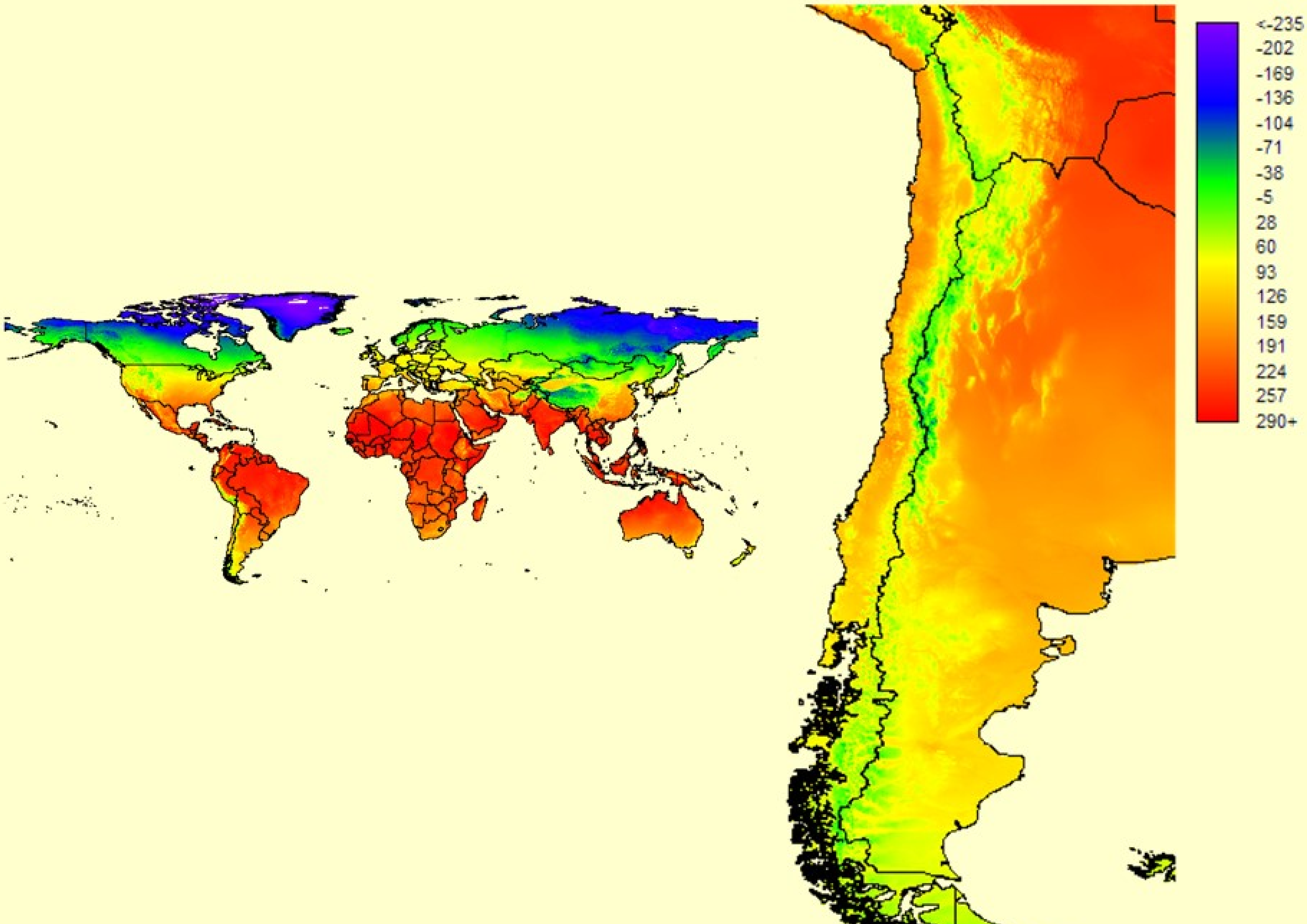
Temperatura Mínima Media Mensual (1,2,3,…….12)

Temperatura Máxima Media Mensual (1,2,3,…….12)

Temperatura Media Mensual (1,2,3,…….12)

Precipitación (1,2,3,…….12)



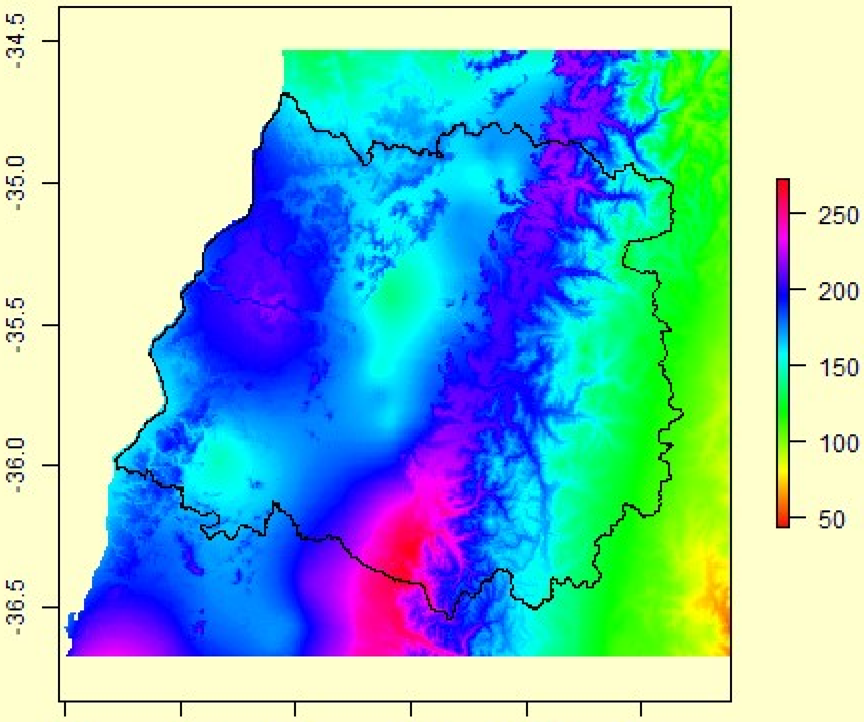


<-235
-202
-169
-136
-104
-71
-38
-5
28
60
93
126
159
191
224
257
290+

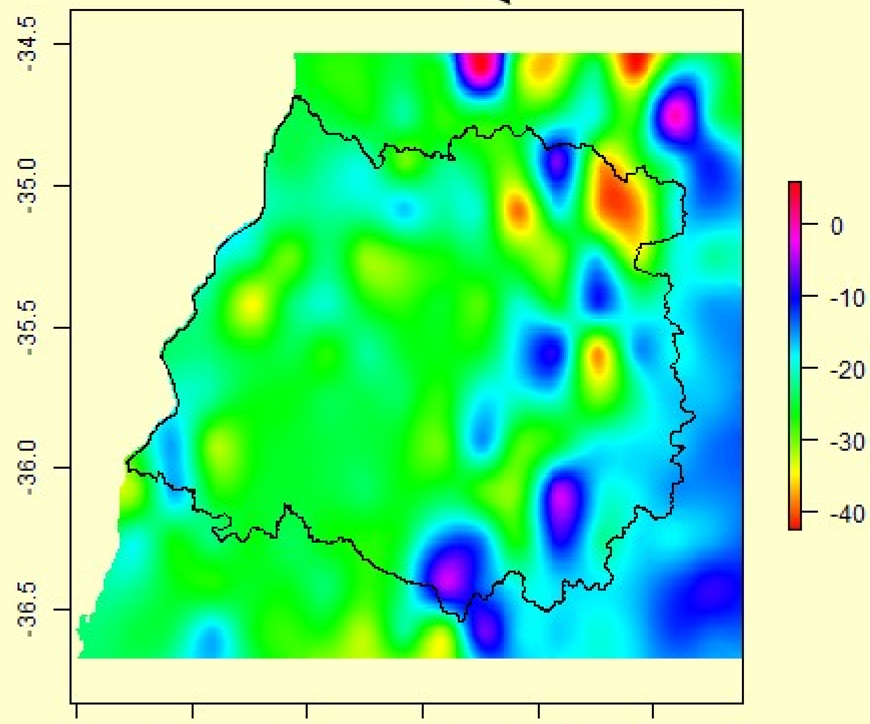
BIOCLIM

BIO1 = Temperatura Media Anual
BIO2 = Rango Diario Diurno (Tmax - Tmin)
BIO3 = Isotermalidad (BIO2/BIO7) (* 100)
BIO4 = Temperatura Estacional (Desviacion Estándar*100)
BIO5 = Temperatura Máxima Mes más Cálido
BIO6 = Temperatura Mínima Mes más Frío
BIO7 = Rango de Temperatura Anual (BIO5-BIO6)
BIO8 = Temperatura Media Estación más Húmeda
BIO9 = Temperatura Media Estación más Seca
BIO10 = Temperatura Media Estación más Cálido
BIO11 = Temperatura Media Estación más Frío
BIO12 = Precipitacion Media Anual
BIO13 = Precipitación Mes más Húmedo
BIO14 = Precipitación Mes más Seco
BIO15 = Precipitacion Estacional (Coeficiente de Variacion)
BIO16 = Precipitacion Estación más Húmeda
BIO17 = Precipitacion Estación más Seca
BIO18 = Precipitacion Estación más Cálida
BIO19 = Precipitacion Estación más Seca

$$X_{i,m} = X_{i,m}^{Baseline} + \Delta X_{i,m}$$

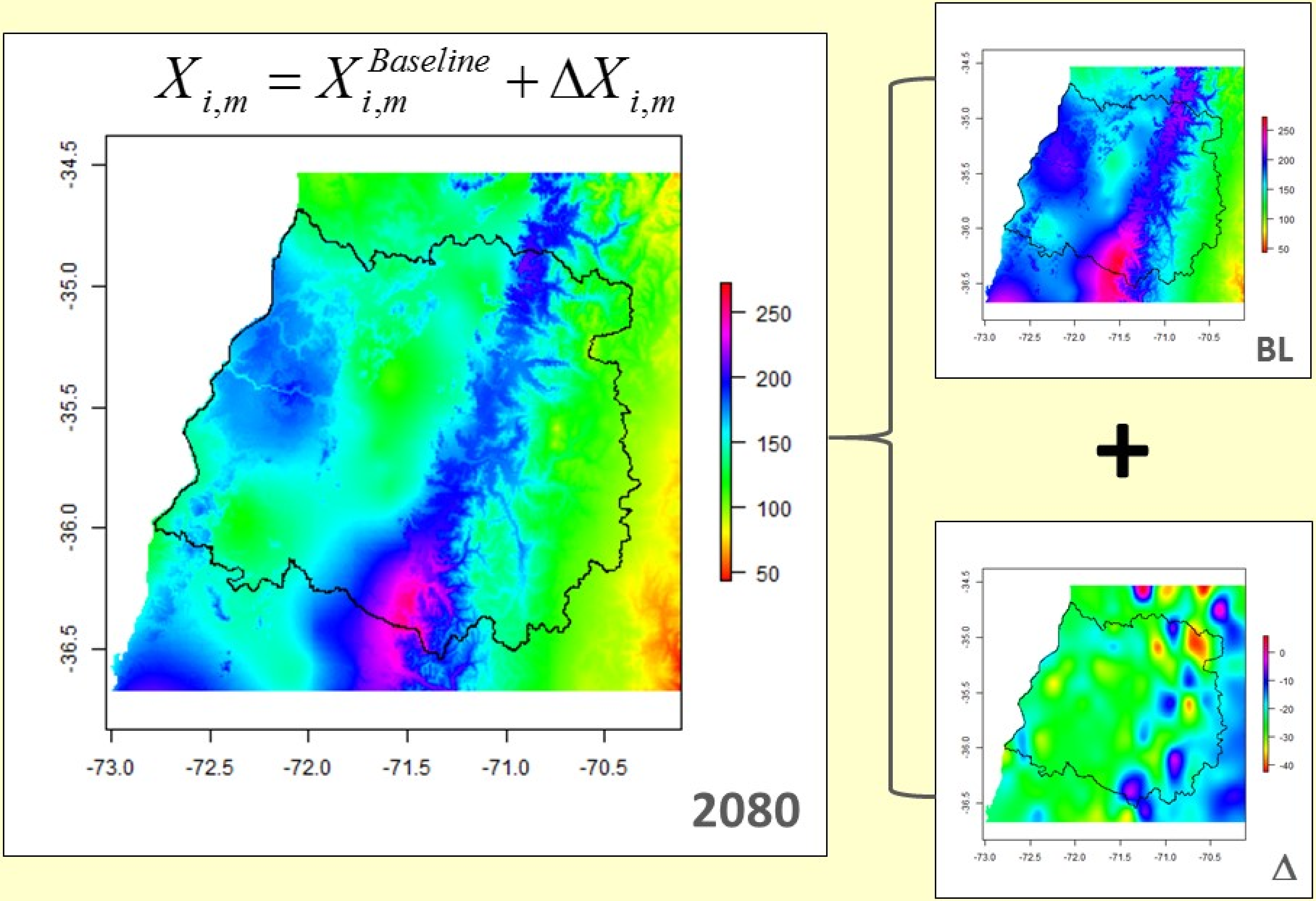


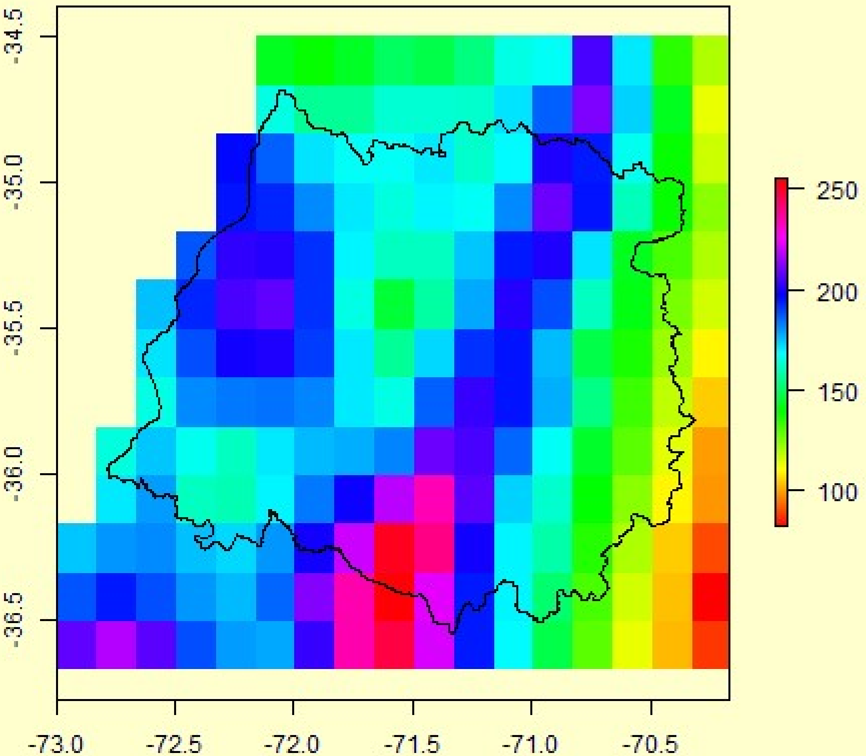
BL



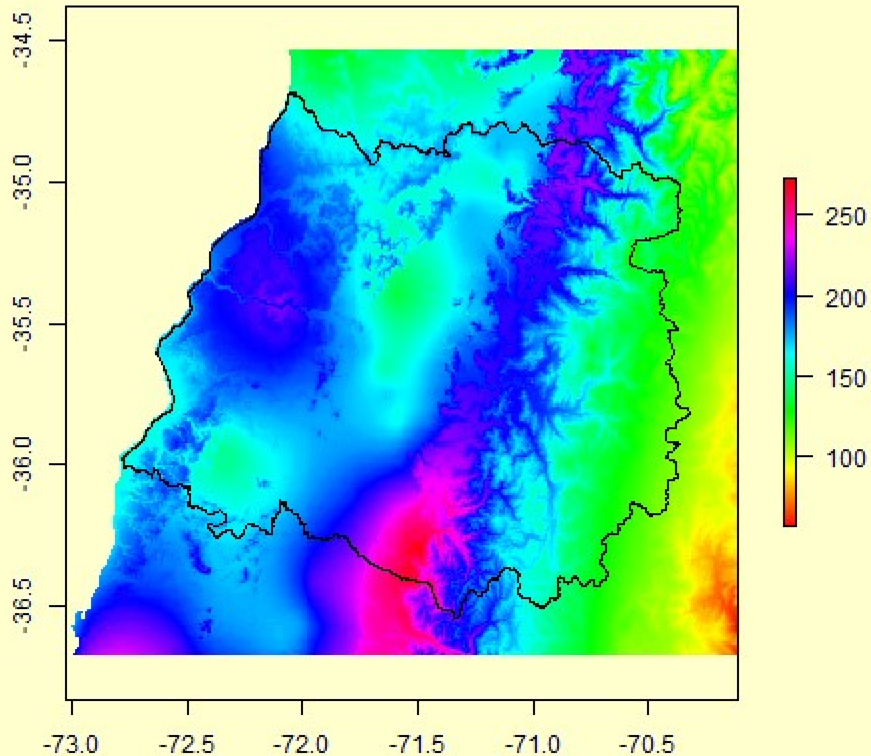
Δ

$$X_{i,m} = X_{i,m}^{Baseline} + \Delta X_{i,m}$$



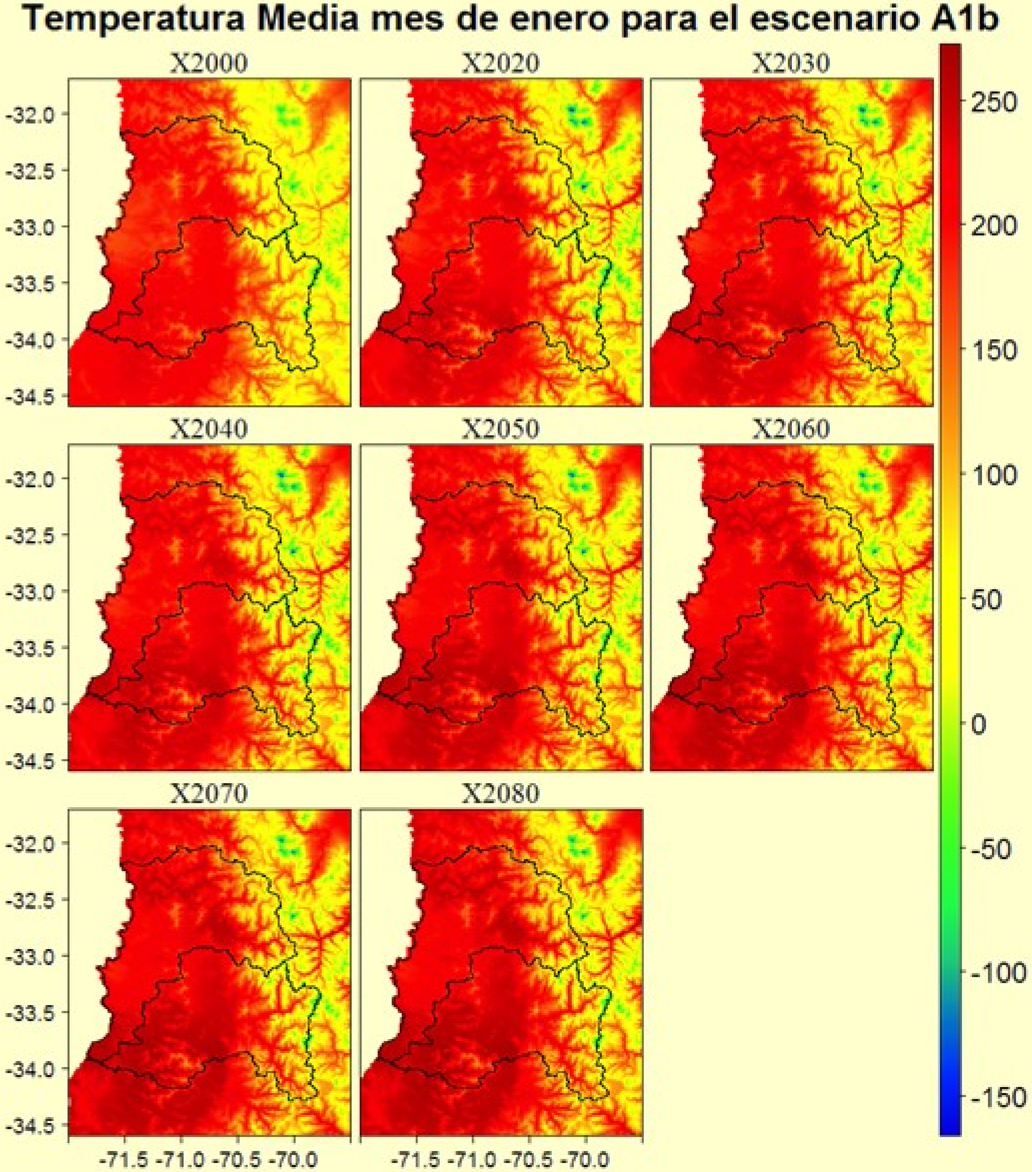


GCM

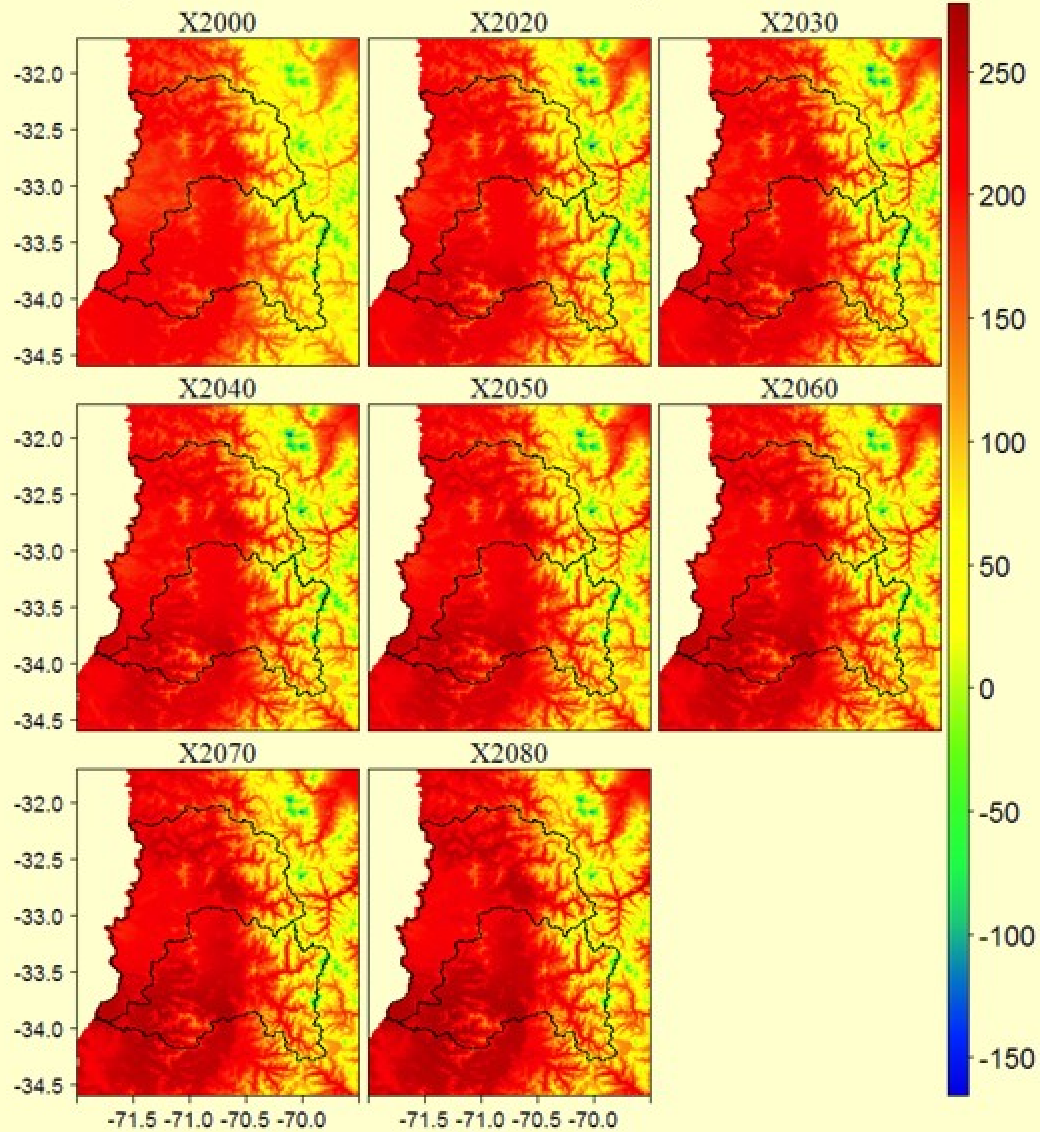


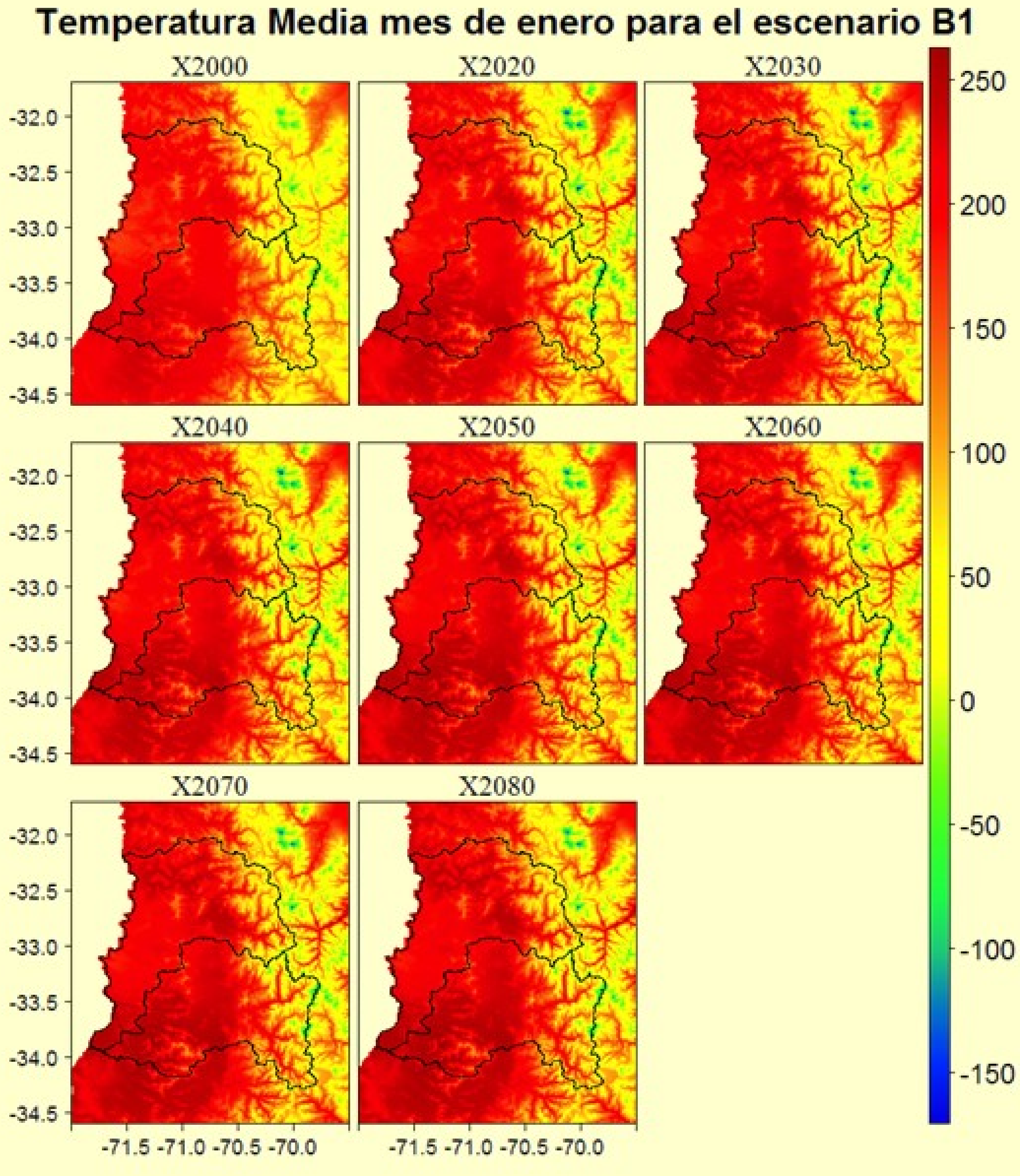
Downscaling

Temperatura

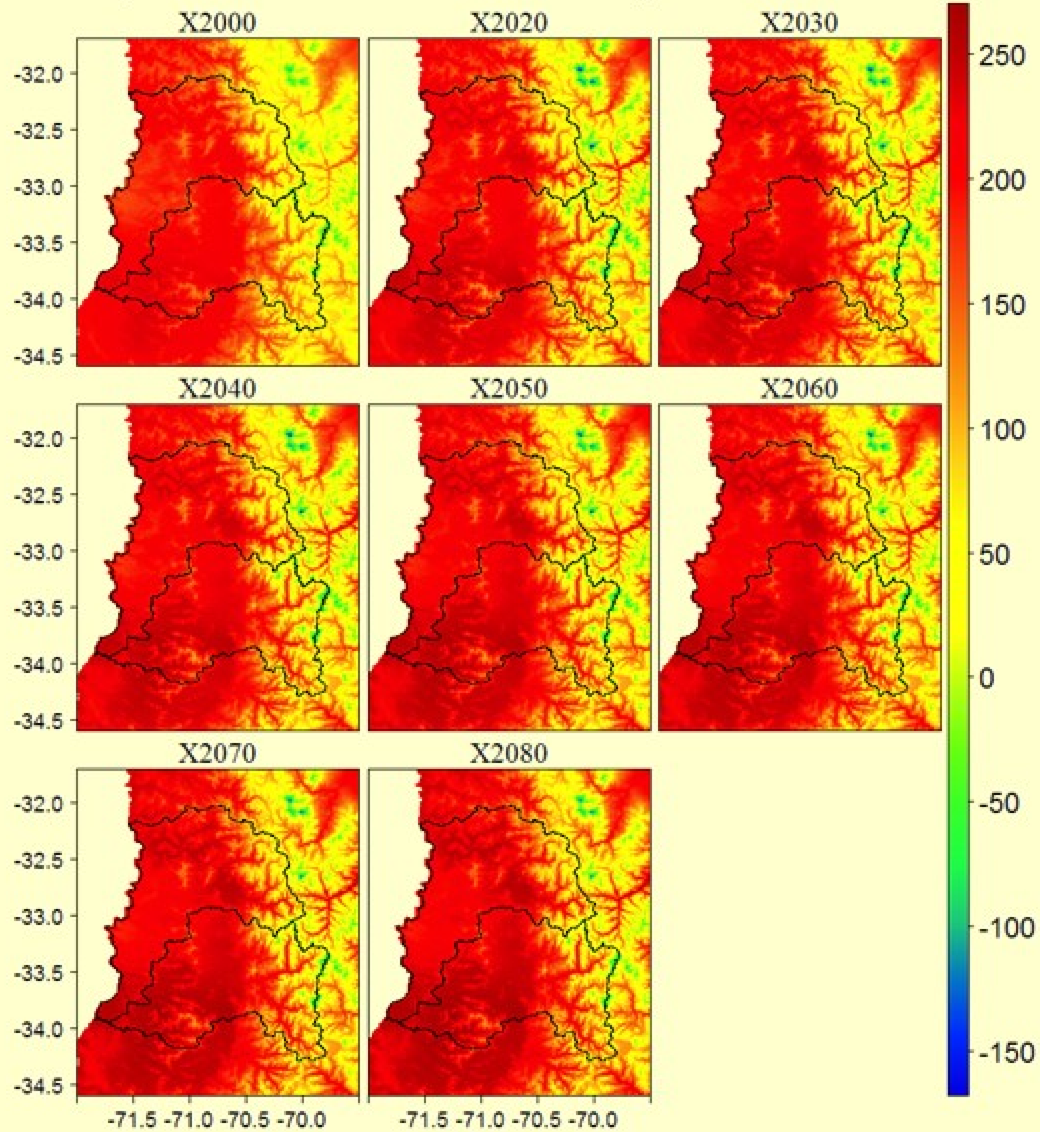


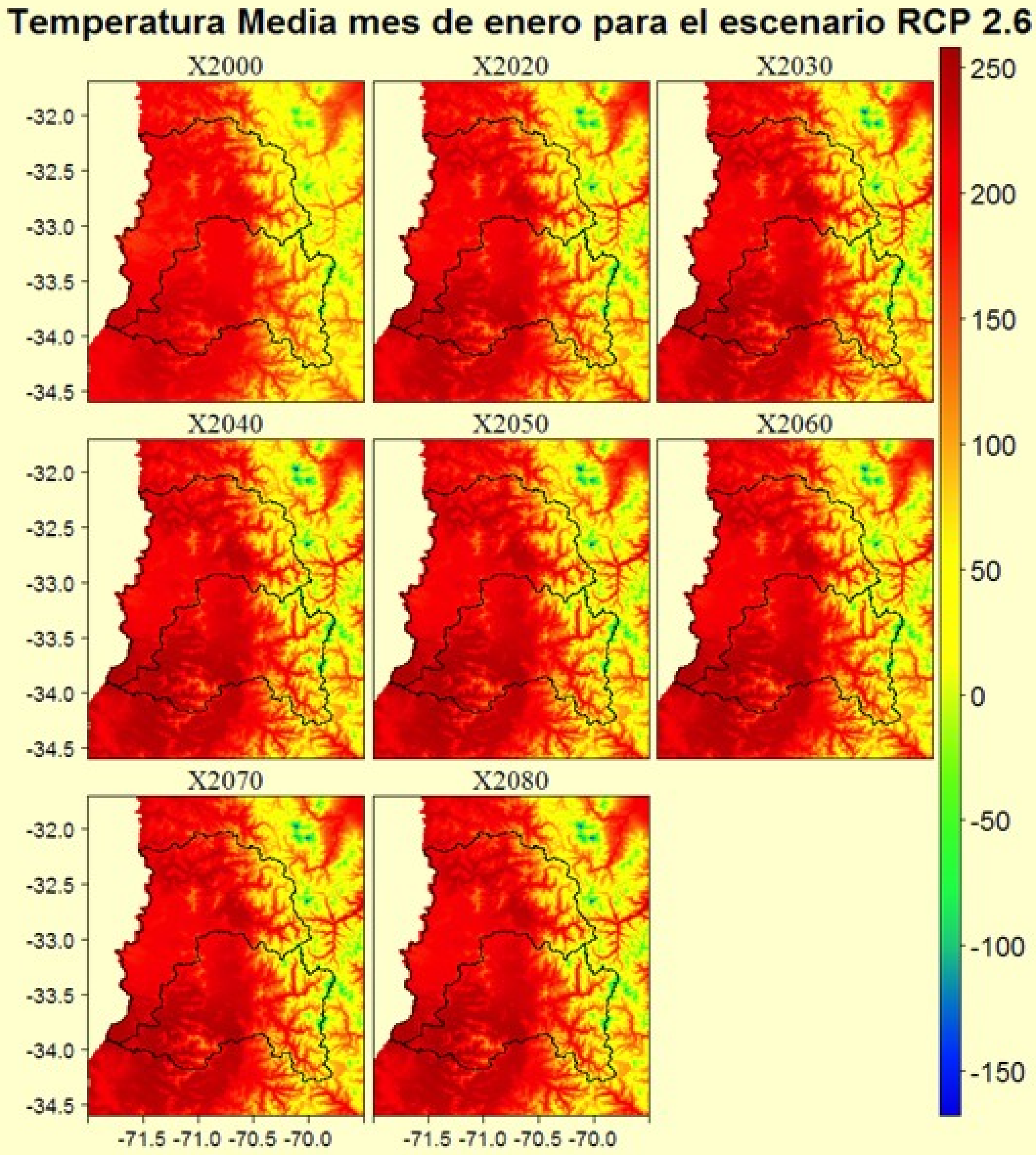
Temperatura Media mes de enero para el escenario A2

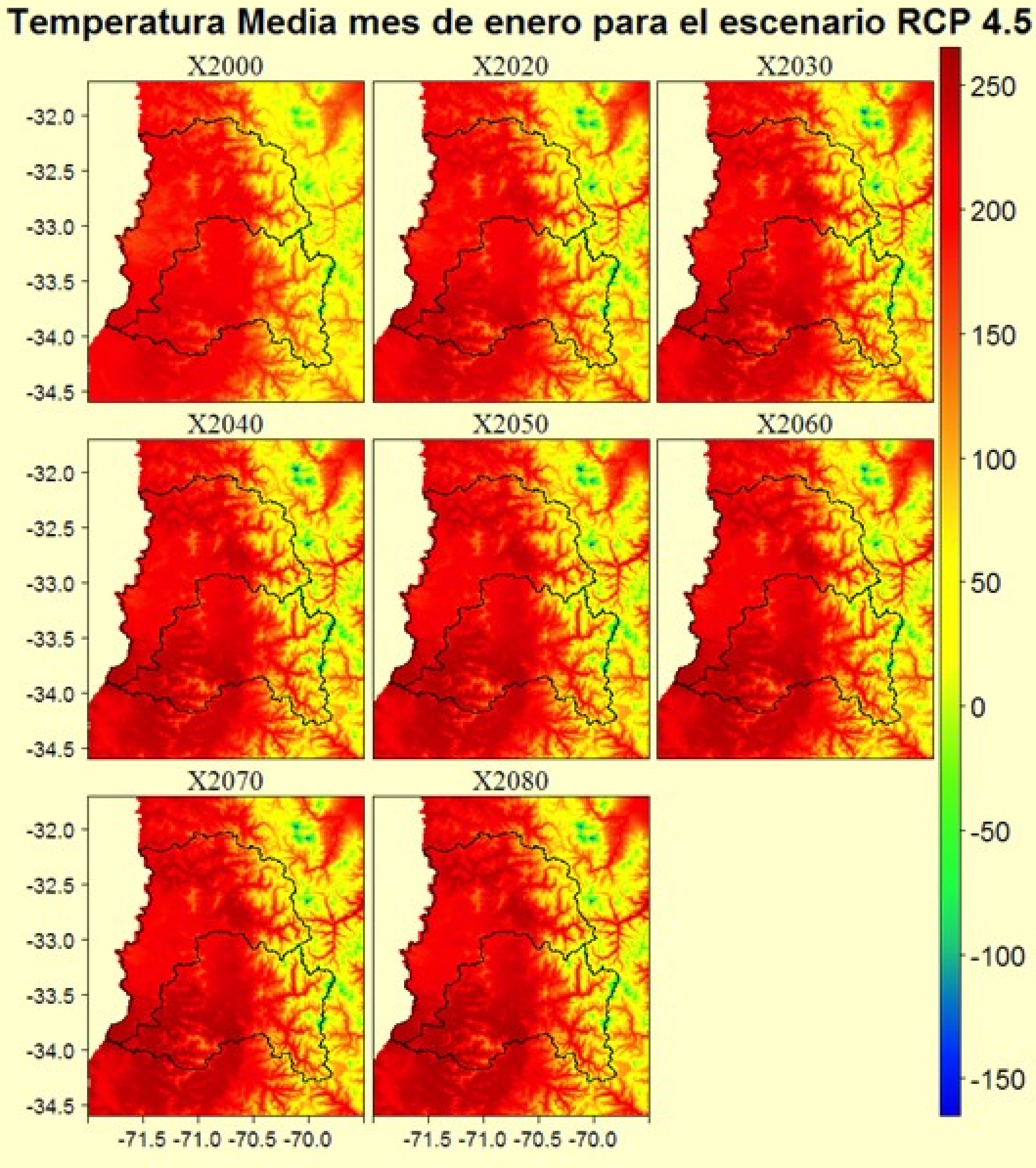



Temperatura Media mes de enero para el escenario B1
X2000
X2020
X2030
X2040
X2050
X2060
X2070
X2080
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-71.5 -71.0 -70.5 -70.0
250
200
150
100
50
0
-50
-100
-150

Temperatura Media mes de enero para el escenario B2

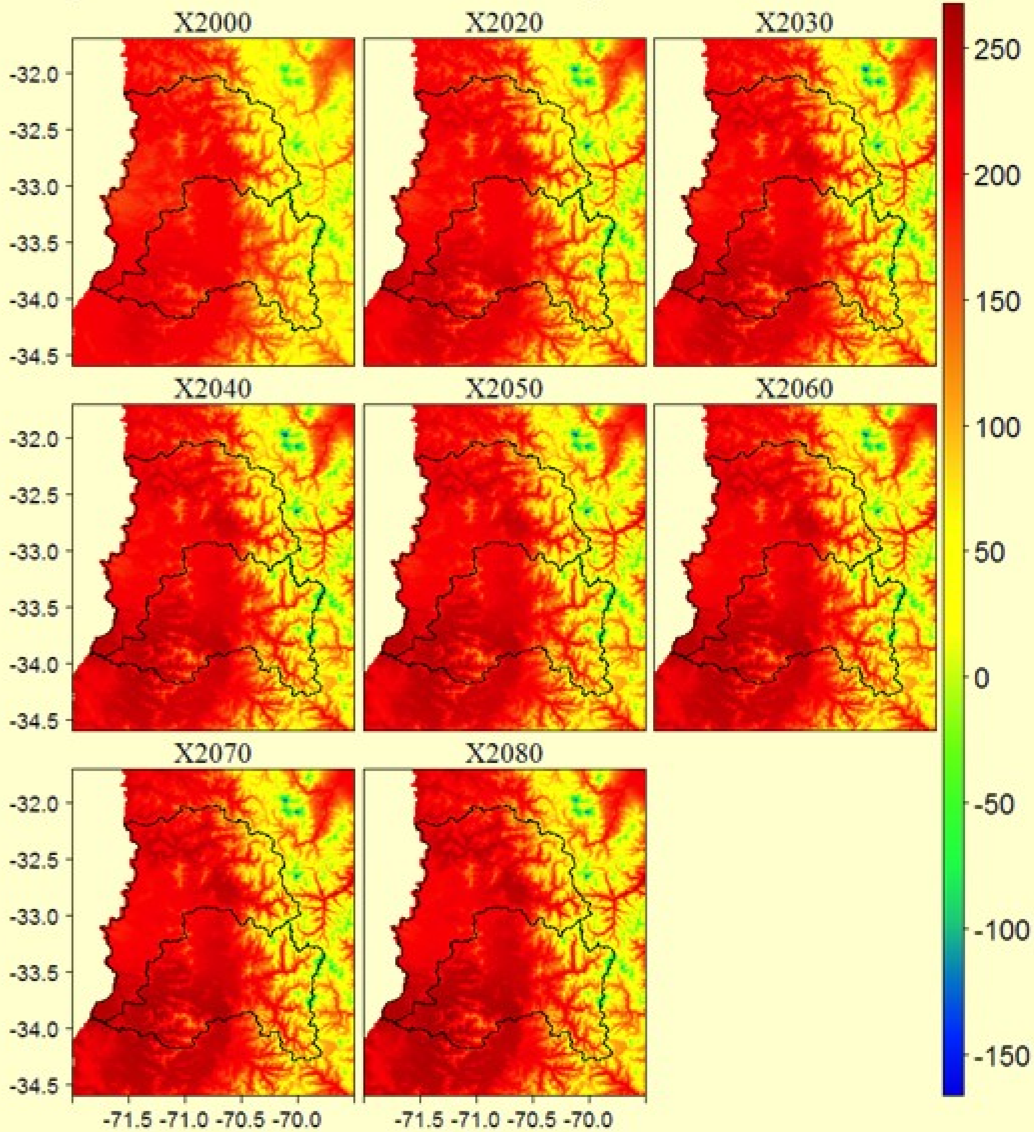



Temperatura Media mes de enero para el escenario RCP 2.6
X2000
X2020
X2030
X2040
X2050
X2060
X2070
X2080
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-71.5 -71.0 -70.5 -70.0
250
200
150
100
50
0
-50
-100
-150

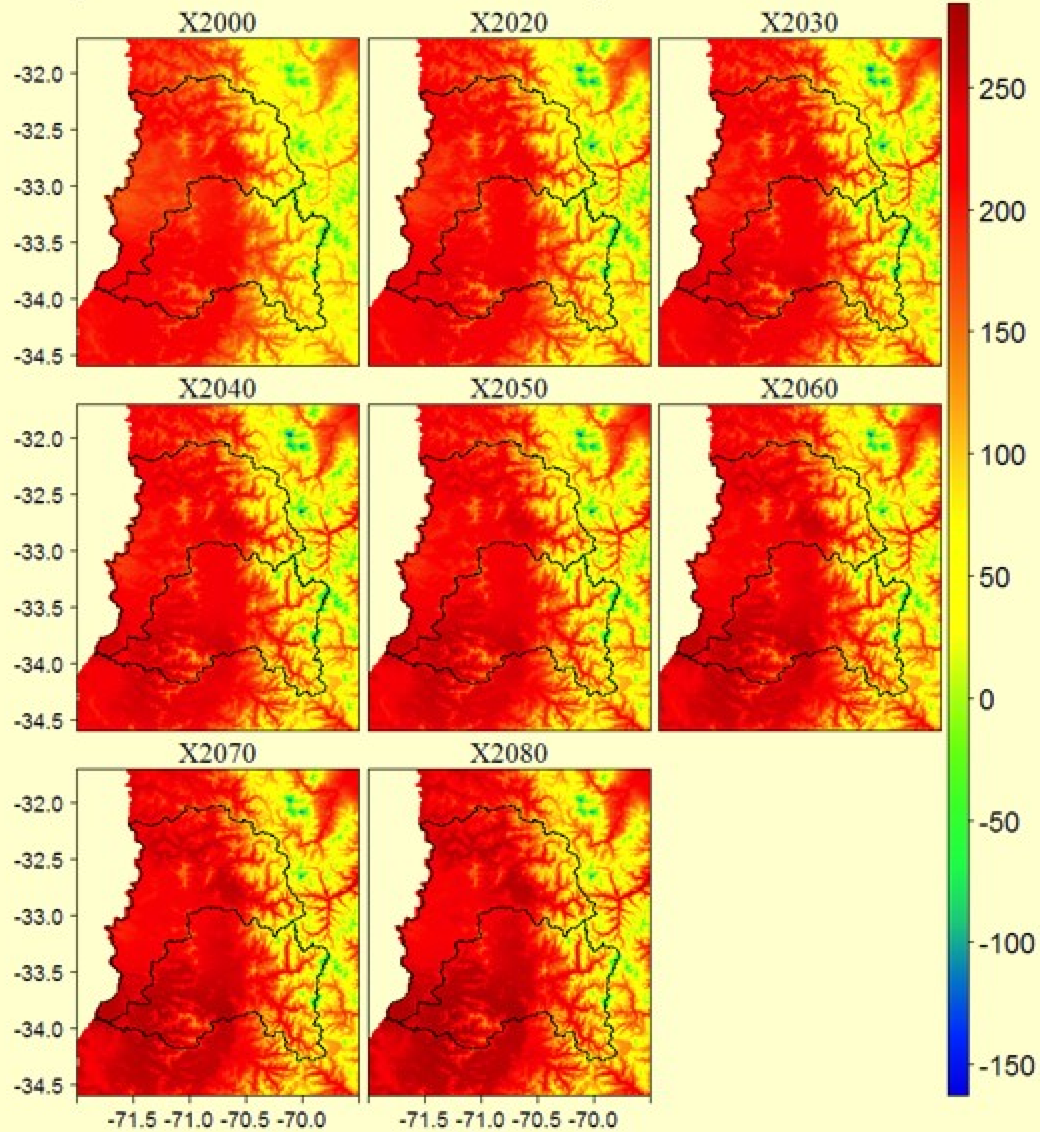


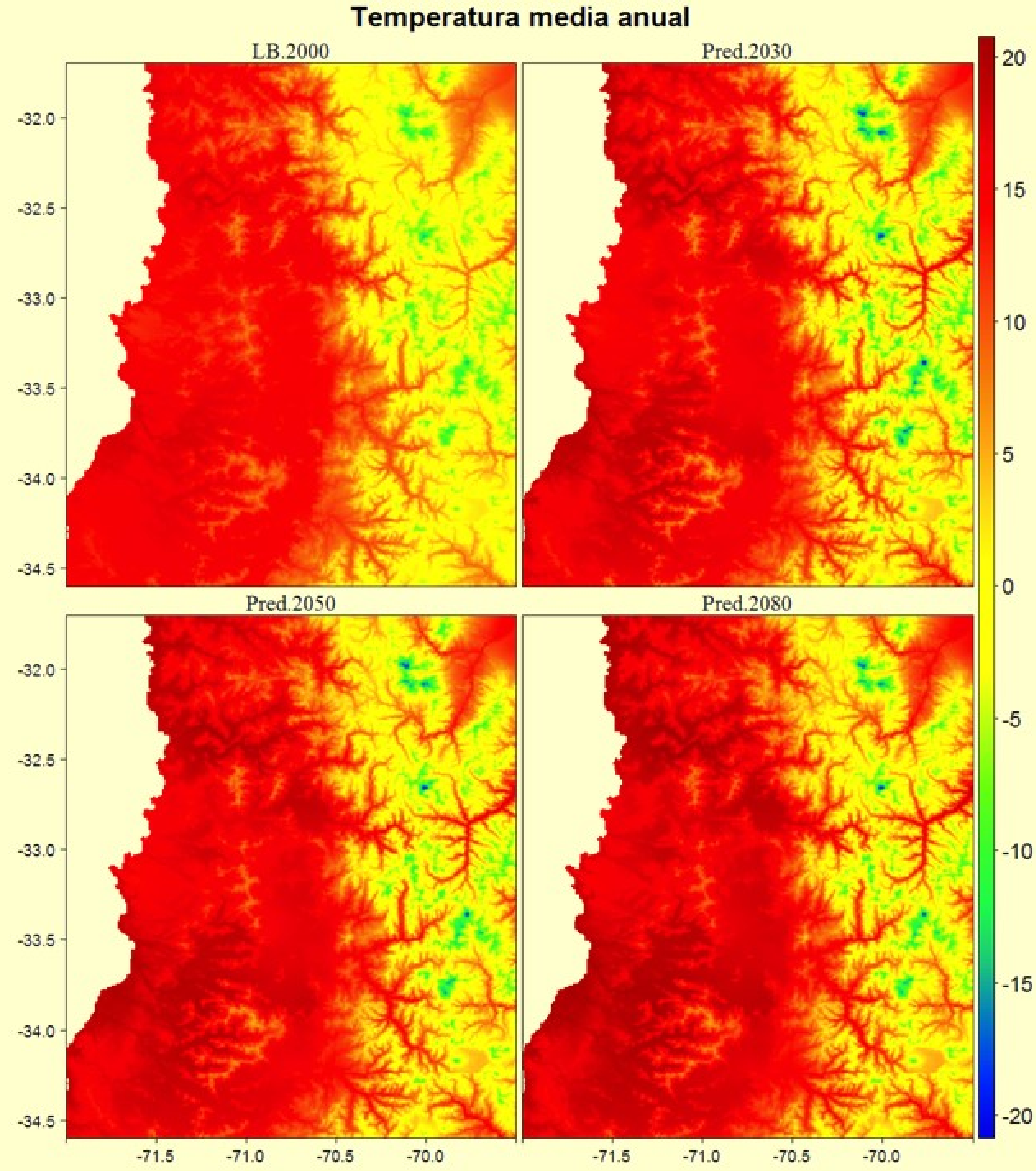
Temperatura Media mes de enero para el escenario RCP 4.5
X2000
X2020
X2030
X2040
X2050
X2060
X2070
X2080
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-71.5 -71.0 -70.5 -70.0
250
200
150
100
50
0
-50
-100
-150

Temperatura Media mes de enero para el escenario RCP 6.0

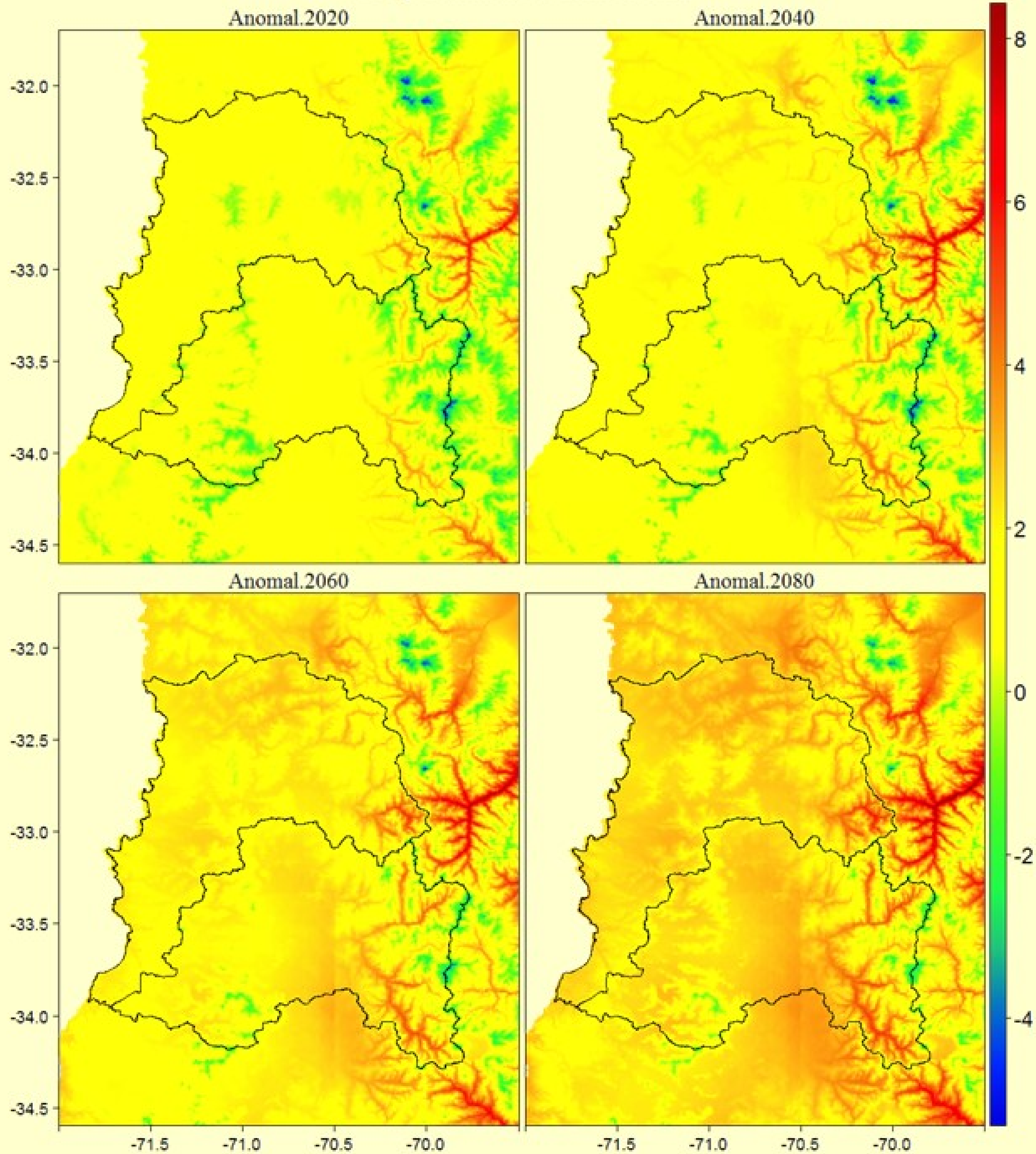


Temperatura Media mes de enero para el escenario RCP 8.5

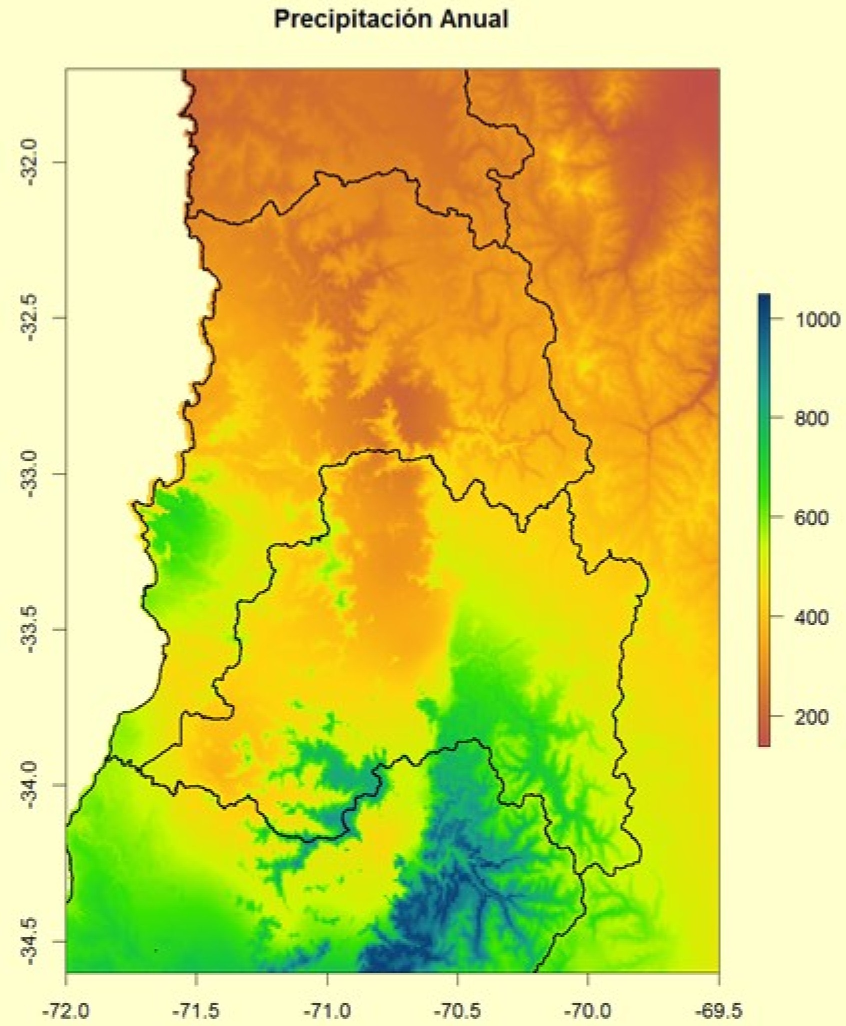


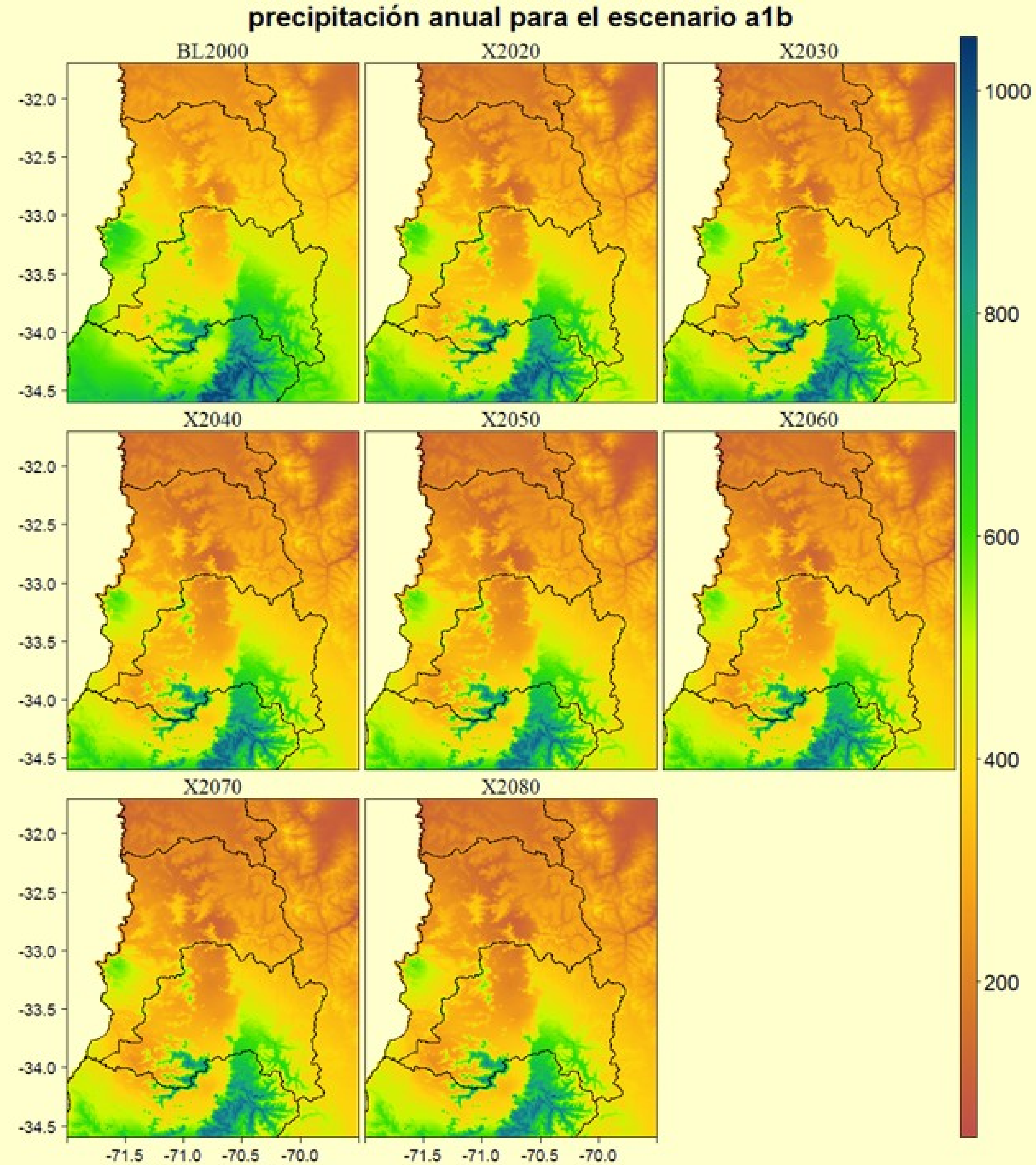

Temperatura media anual
LB.2000
Pred.2030
Pred.2050
Pred.2080
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-71.5
-71.0
-70.5
-70.0
20
15
10
5
0
-5
-10
-15
-20

Temperatura media anual



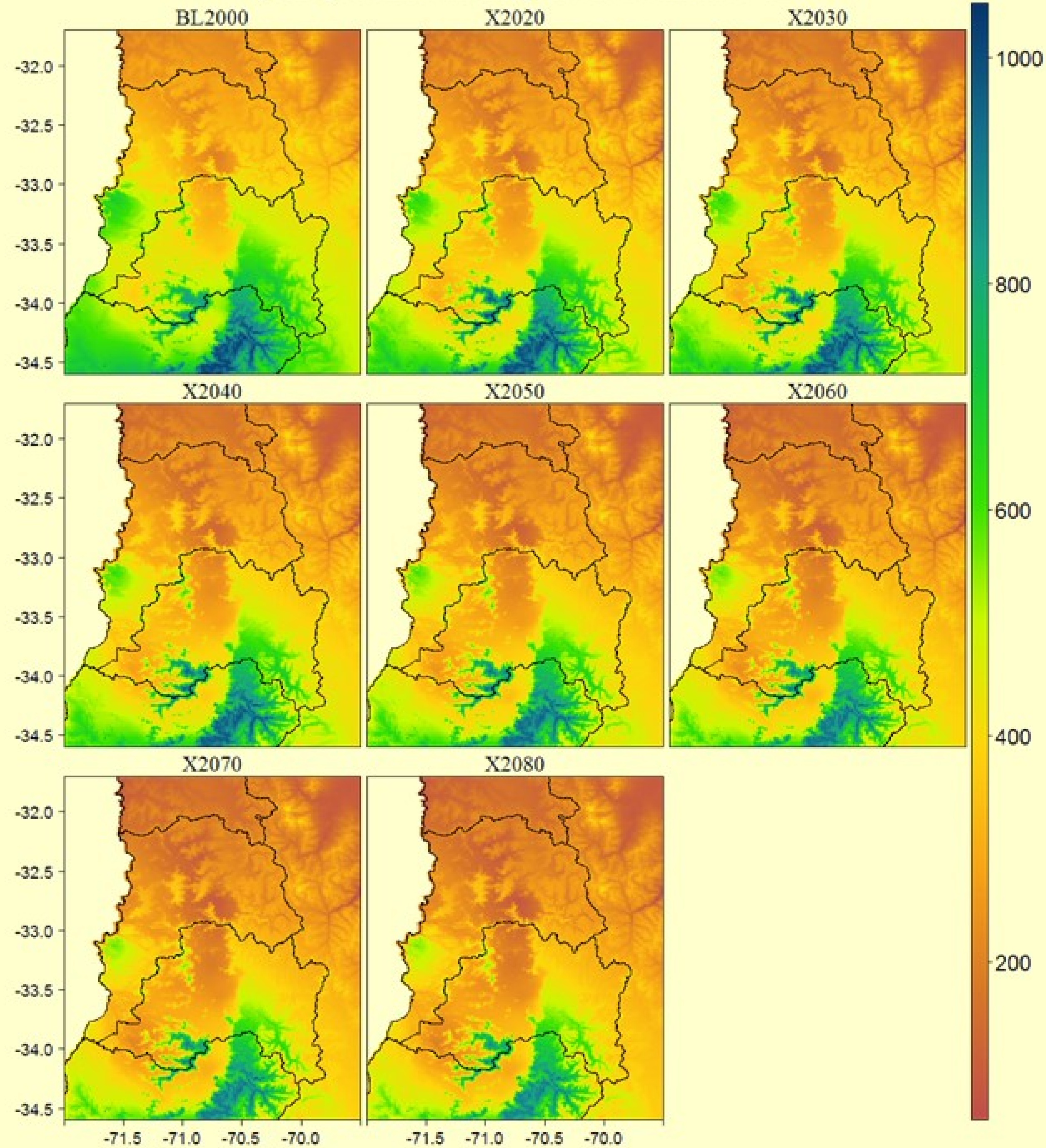
Precipitación

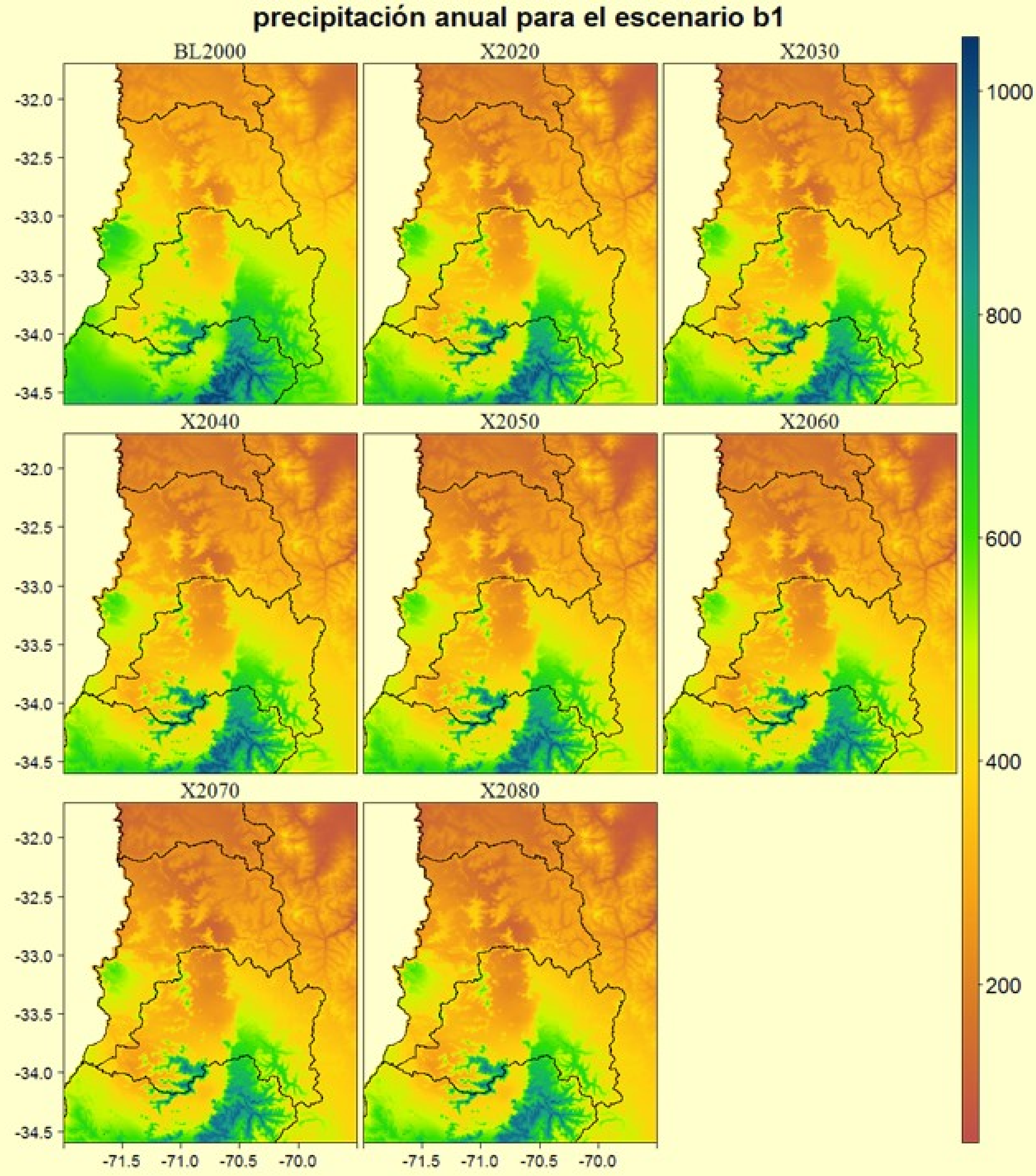




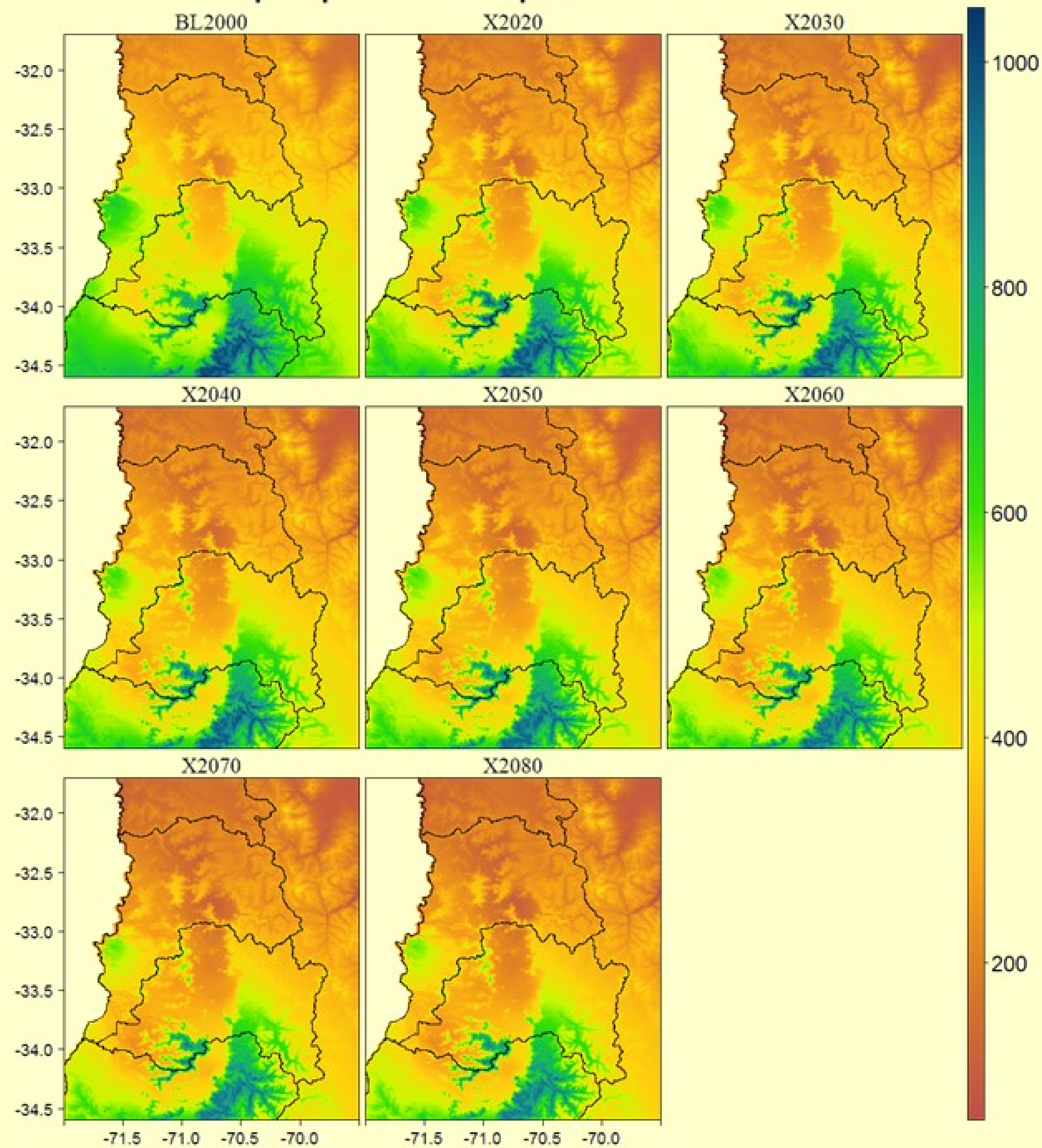
precipitación anual para el escenario a1b
BL2000
X2020
X2030
X2040
X2050
X2060
X2070
X2080
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-71.5
-71.0
-70.5
-70.0
1000
800
600
400
200

precipitación anual para el escenario a2

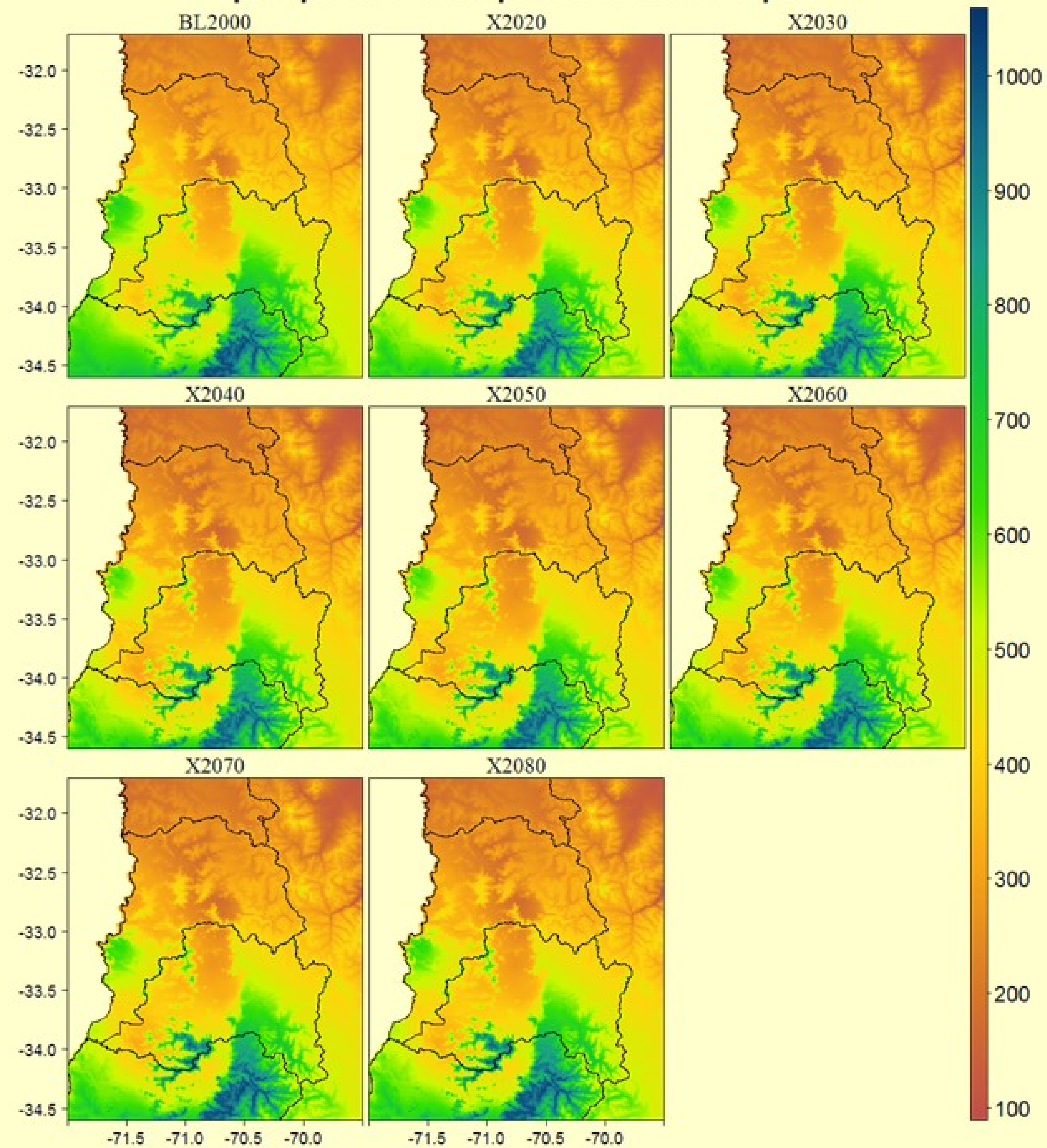



precipitación anual para el escenario b1
BL2000
X2020
X2030
X2040
X2050
X2060
X2070
X2080
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-71.5
-71.0
-70.5
-70.0
1000
800
600
400
200

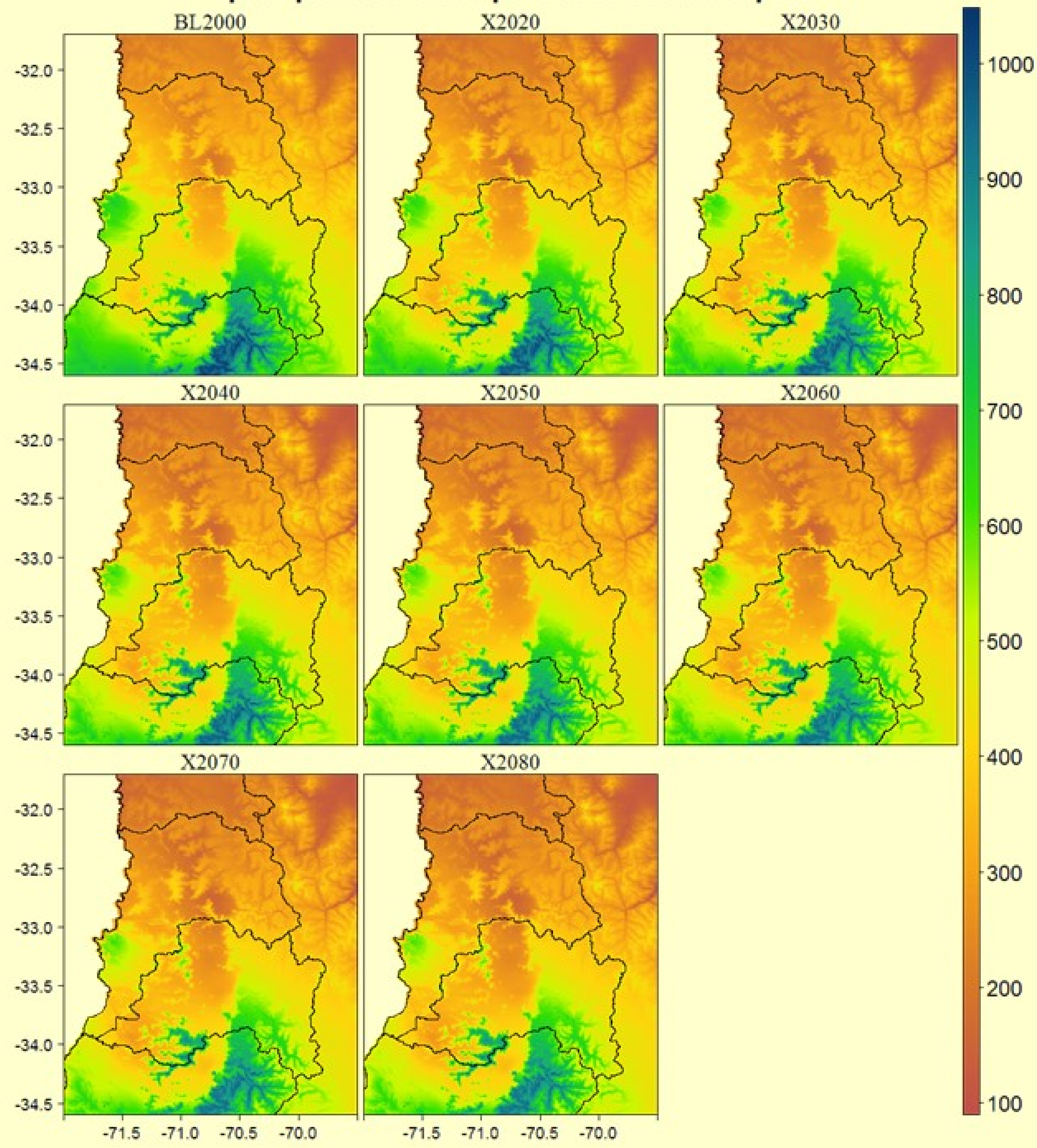
precipitación anual para el escenario b2



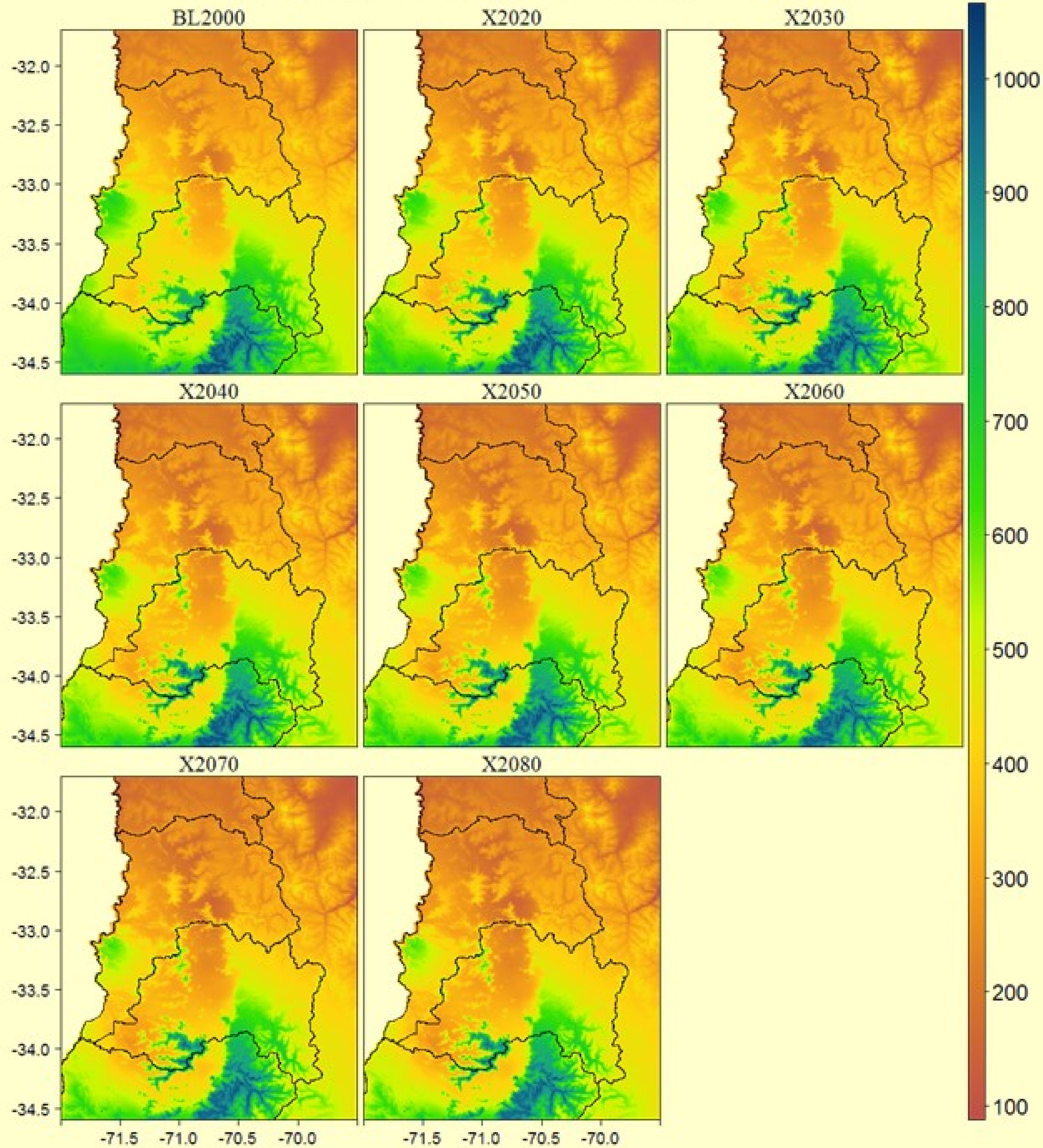
precipitación anual para el escenario rcp2.6



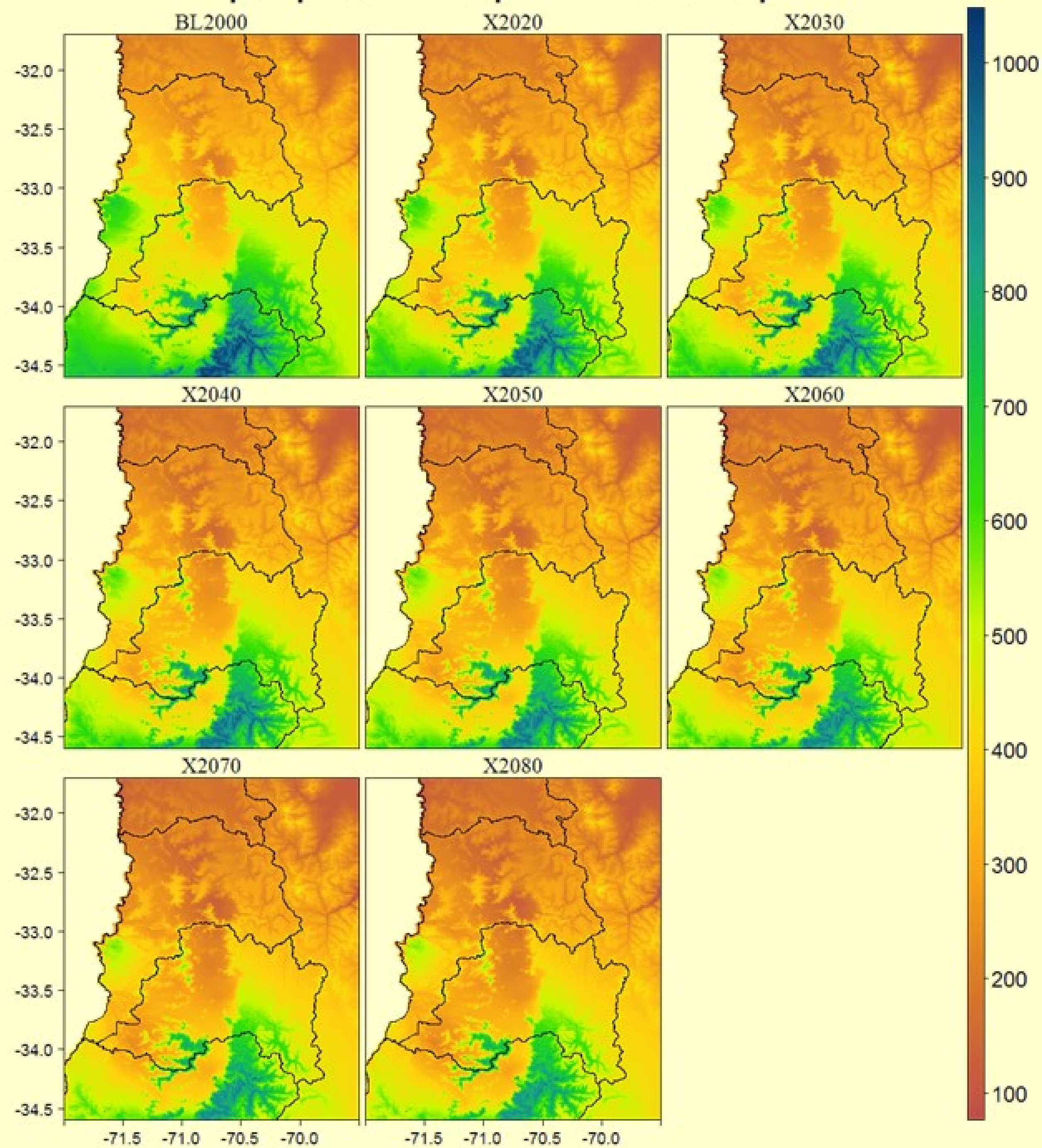
precipitación anual para el escenario rcp4.5



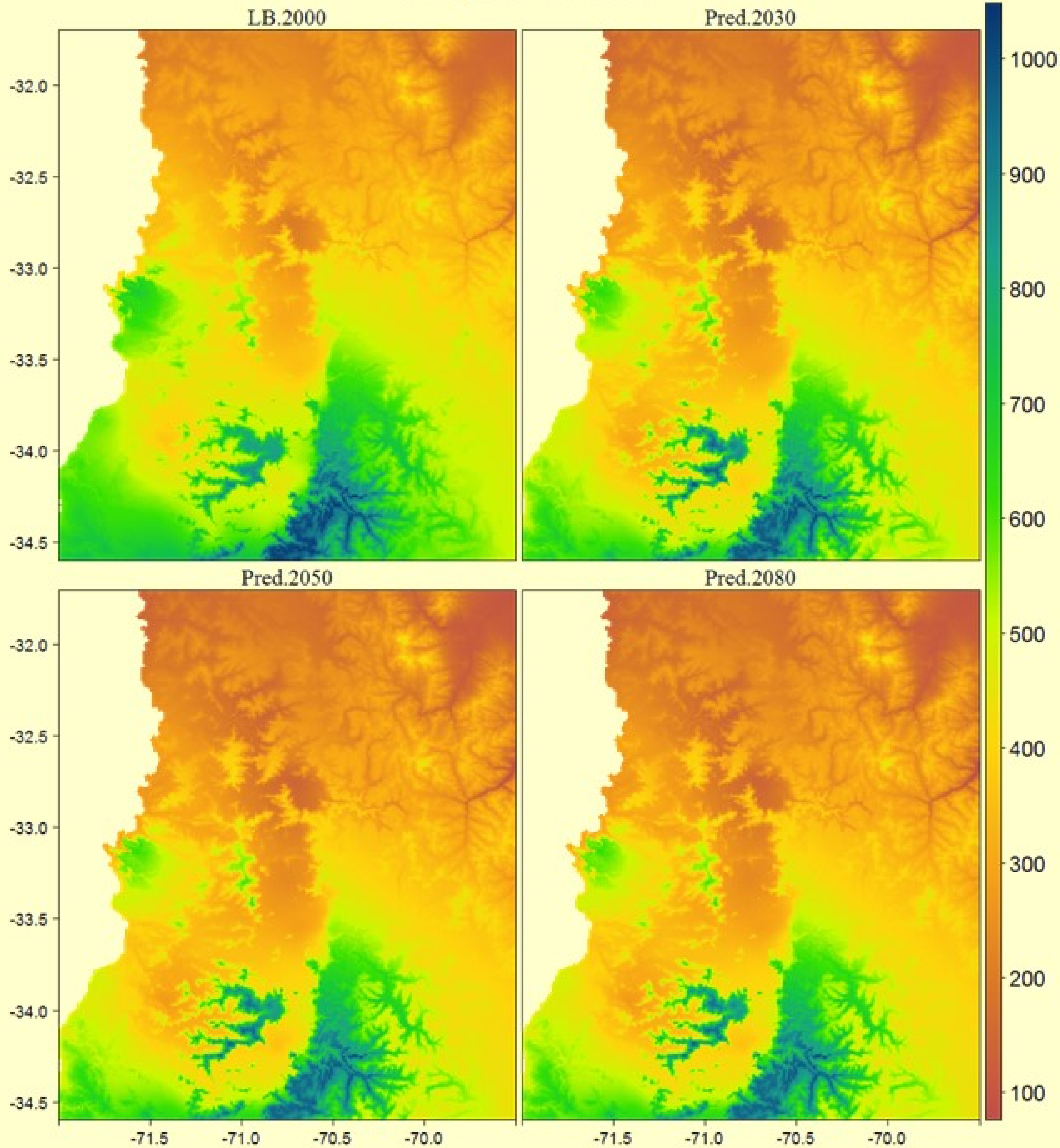
precipitación anual para el escenario rcp6.0



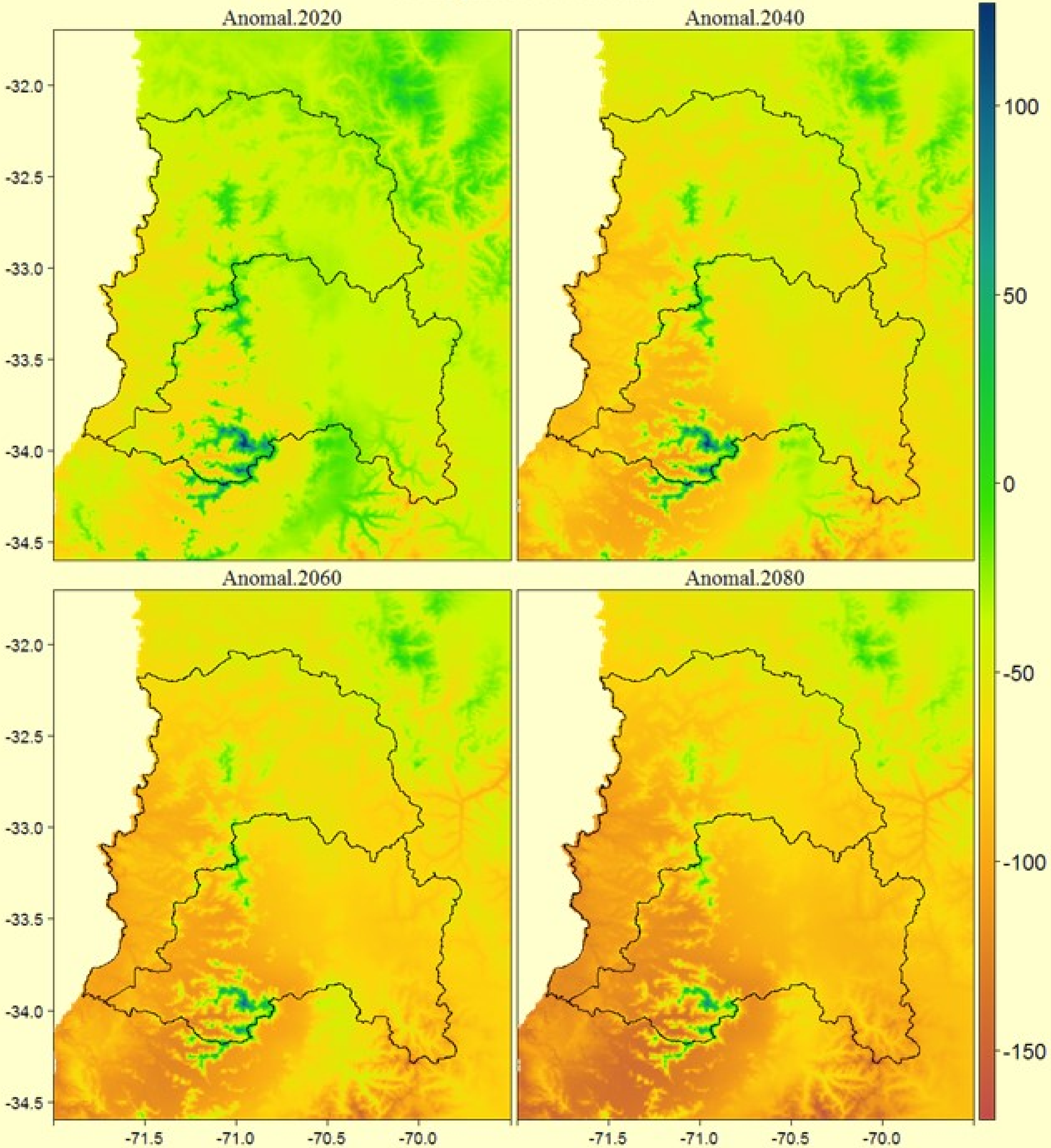
precipitación anual para el escenario rcp8.5



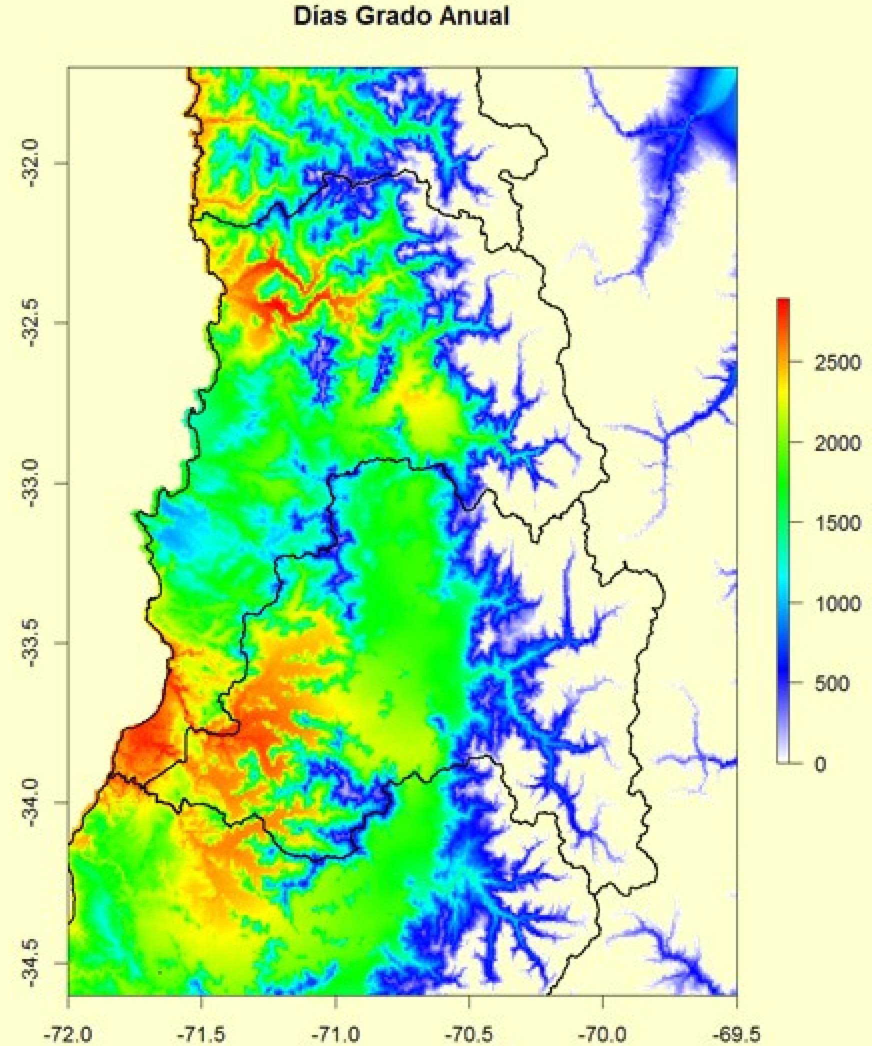
Precipitación anual



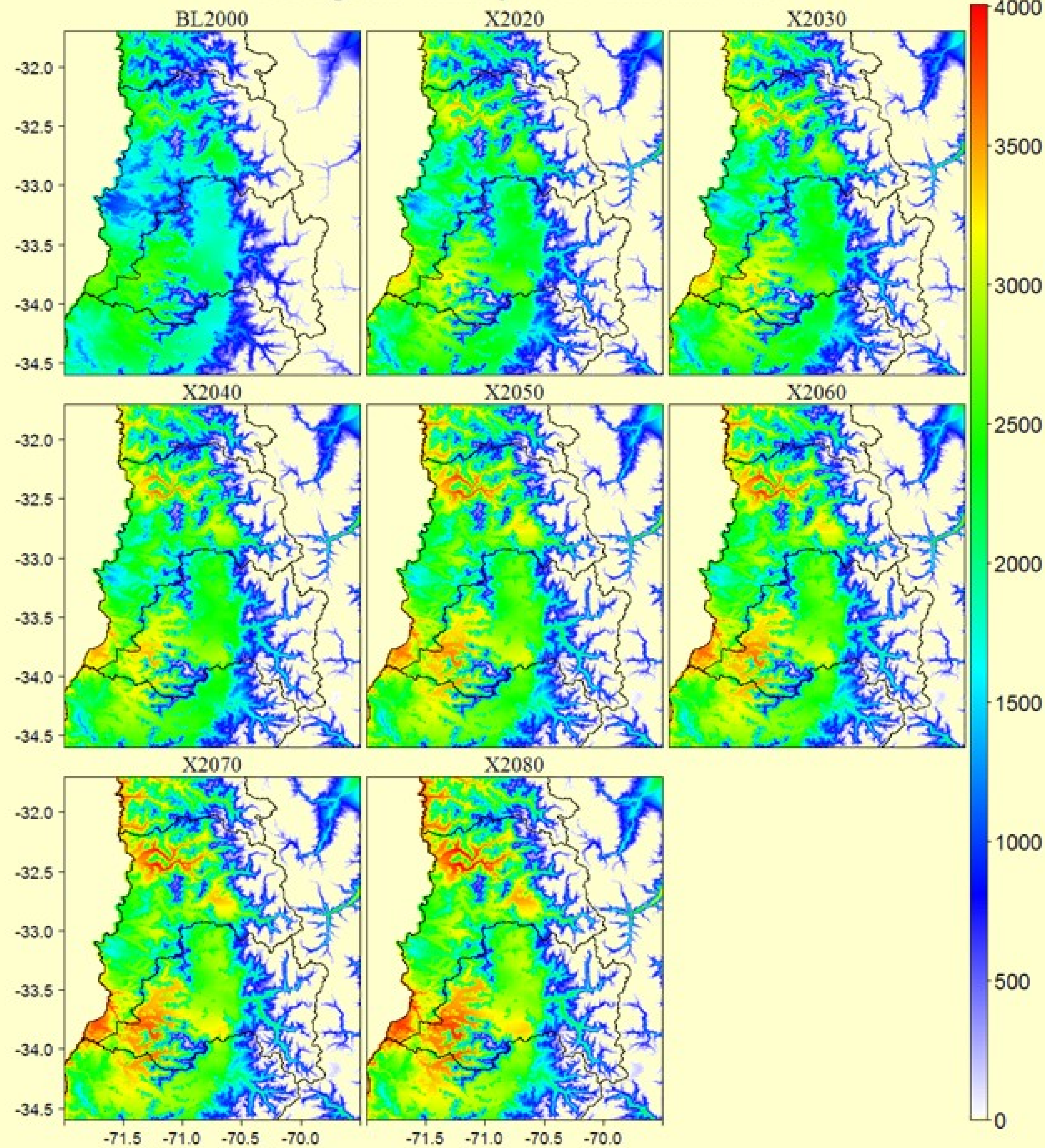
Precipitación anual



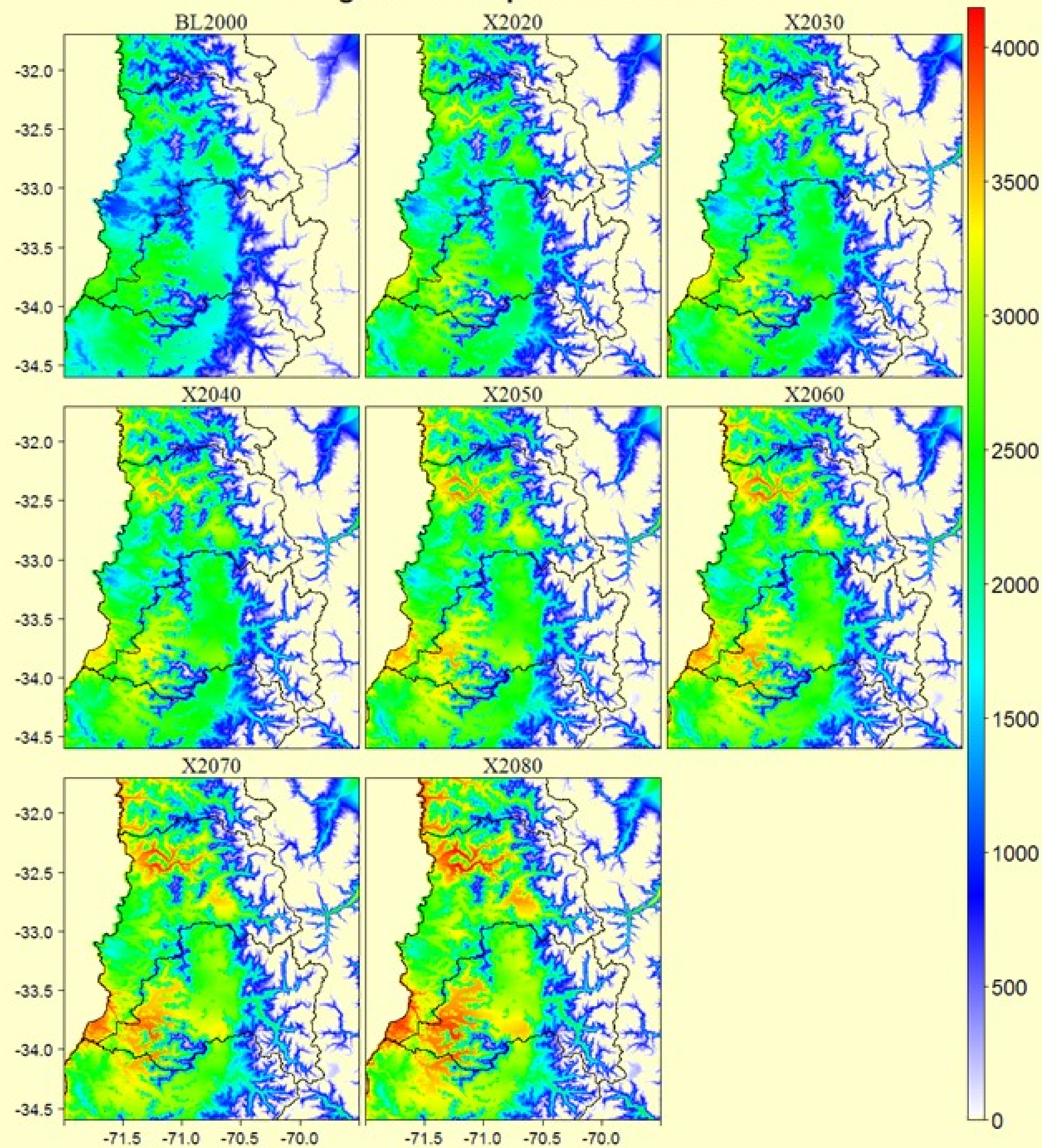
Días Grado


Días Grado Anual
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-72.0
-71.5
-71.0
-70.5
-70.0
-69.5
2500
2000
1500
1000
500
0

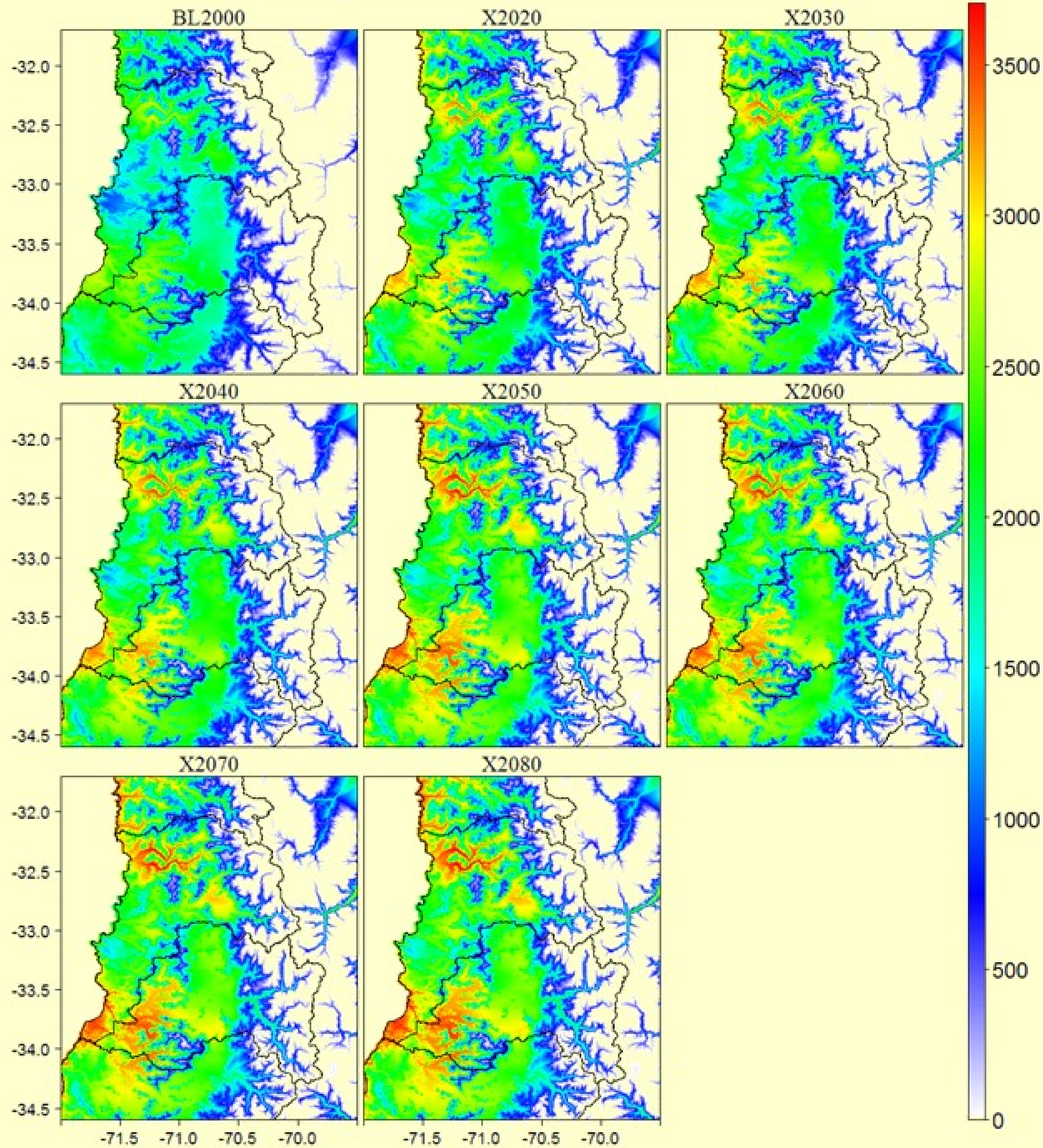
Días grado anual para el escenario a1b



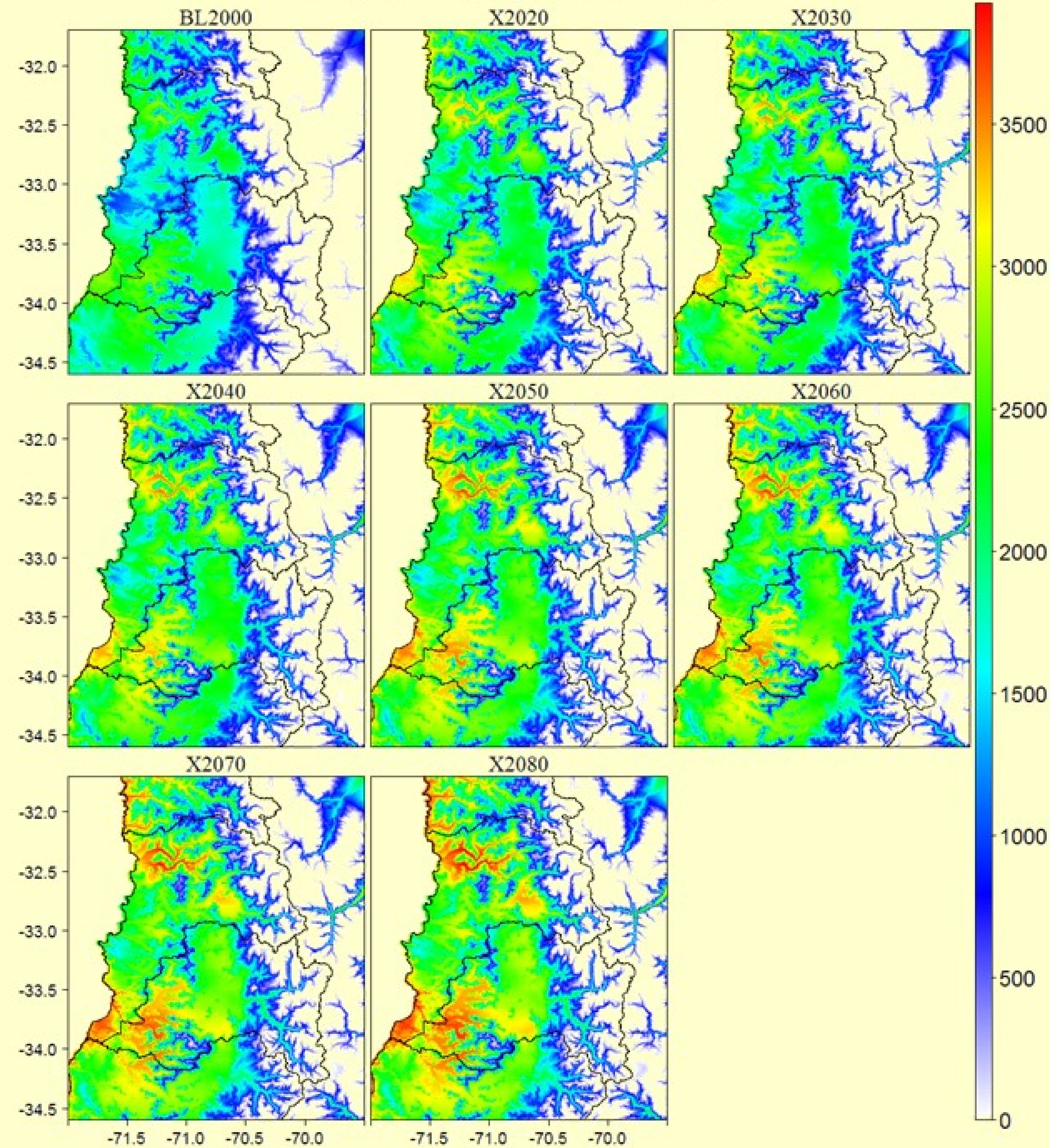
Días grado anual para el escenario a2



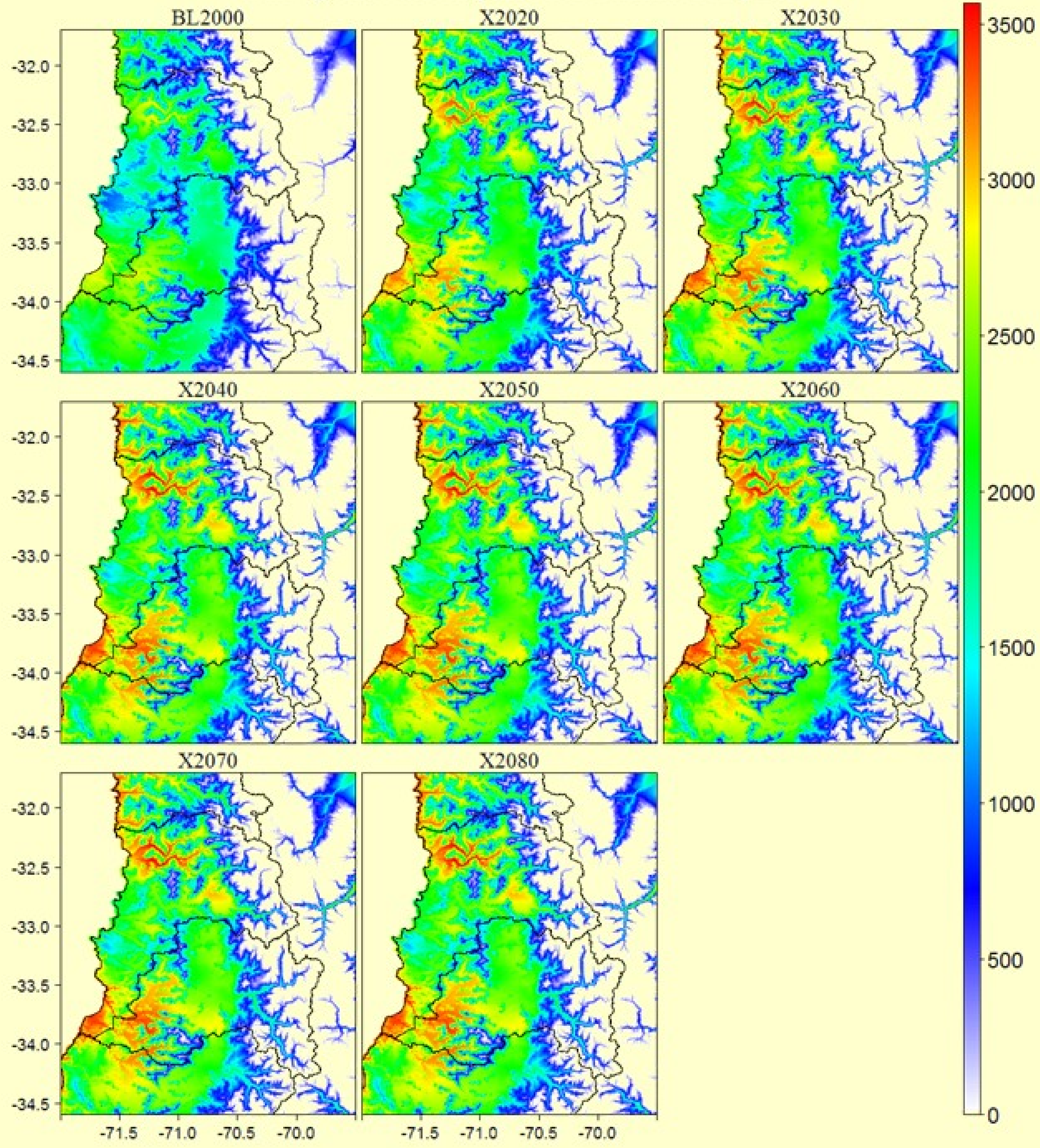
Días grado anual para el escenario b1



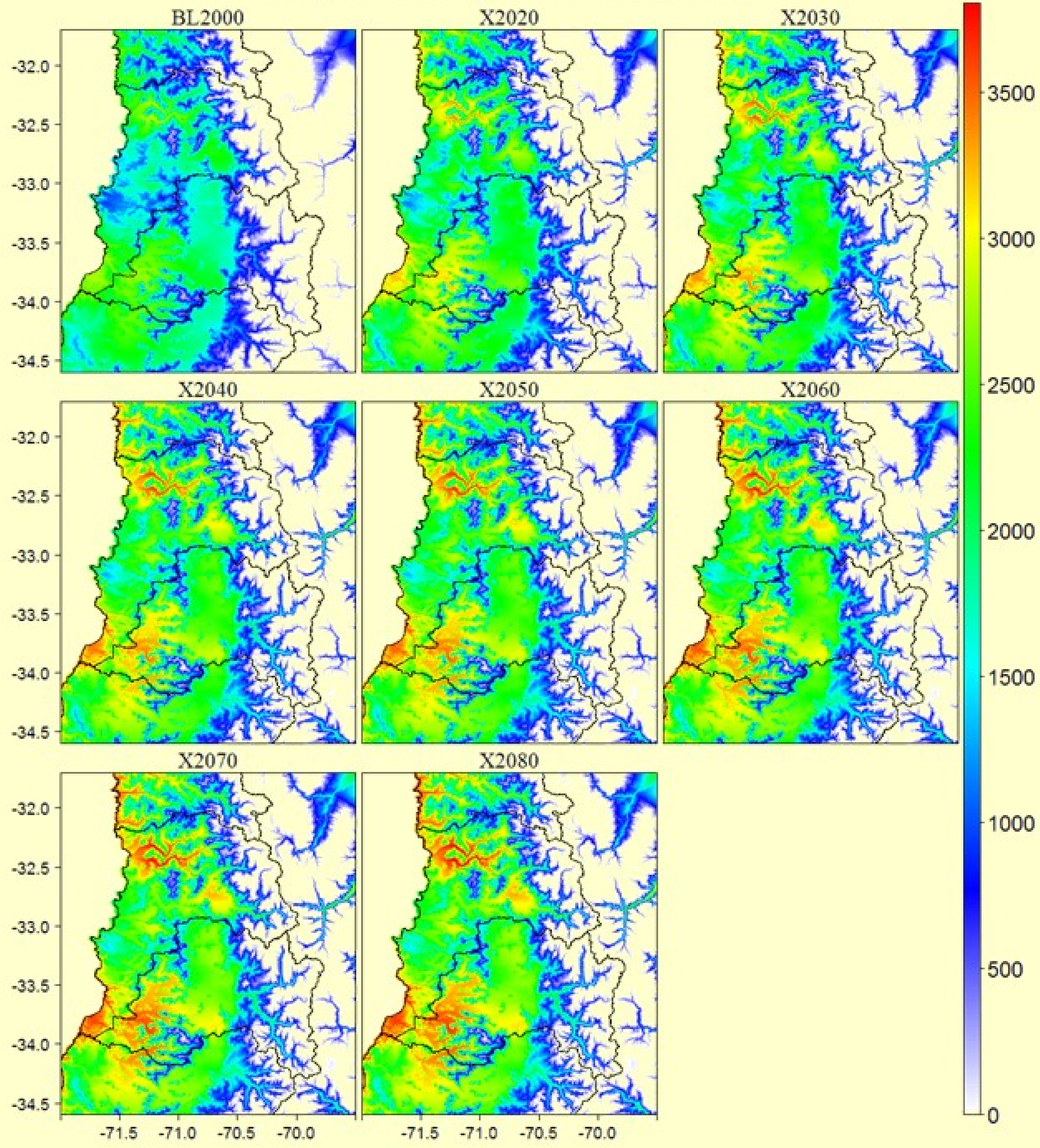
Días grado anual para el escenario b2



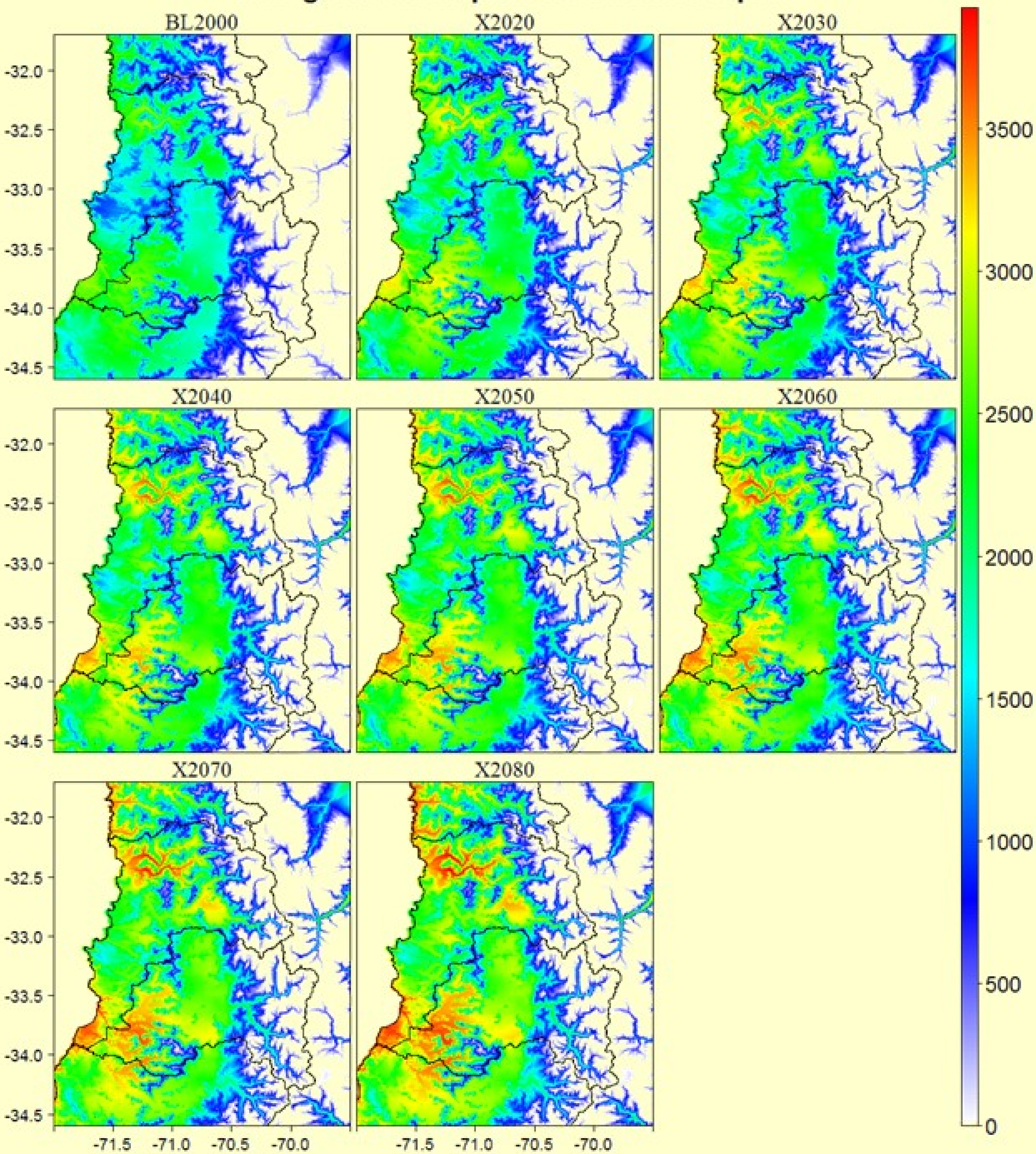
Días grado anual para el escenario rcp2.6

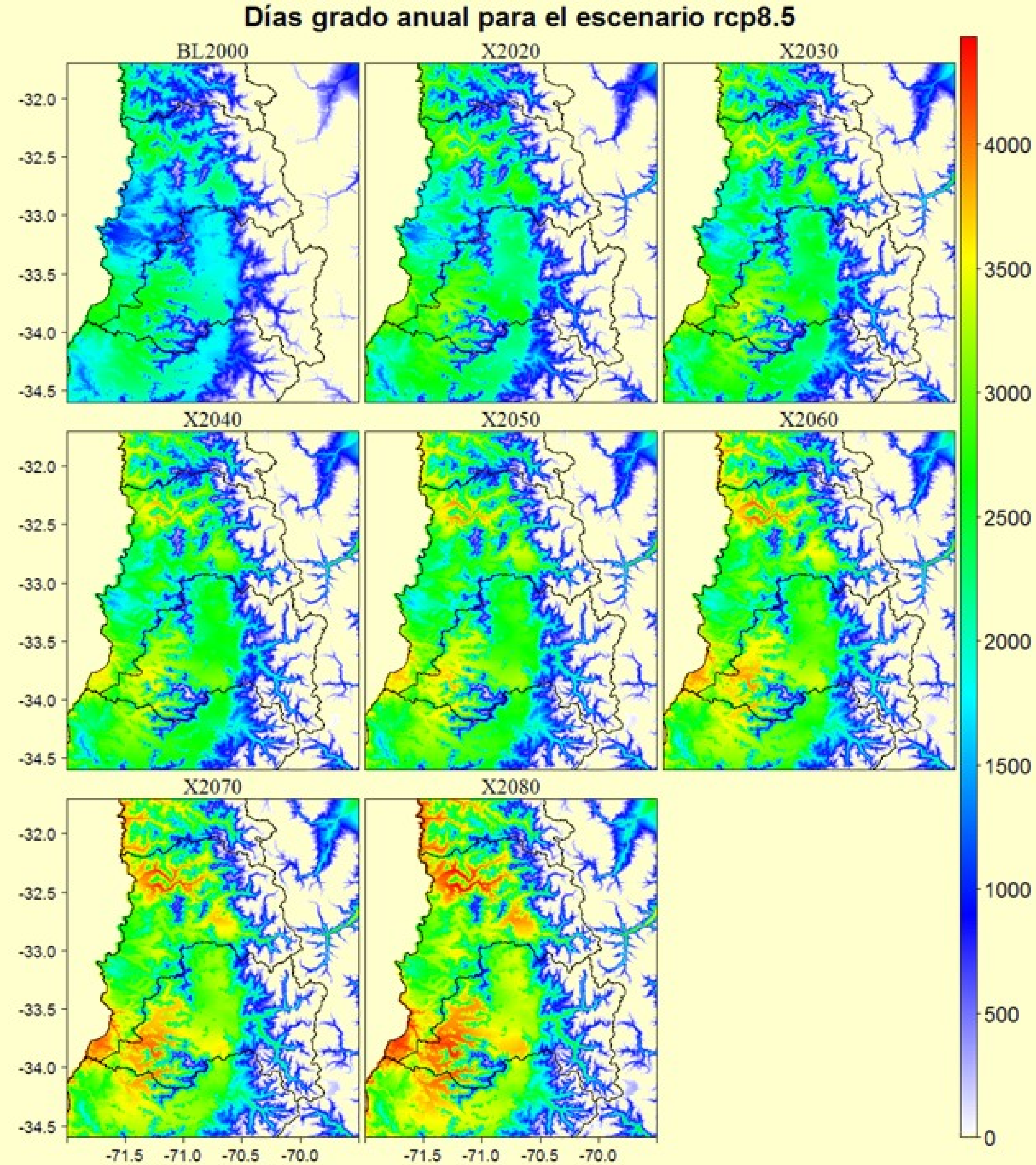


Días grado anual para el escenario rcp4.5

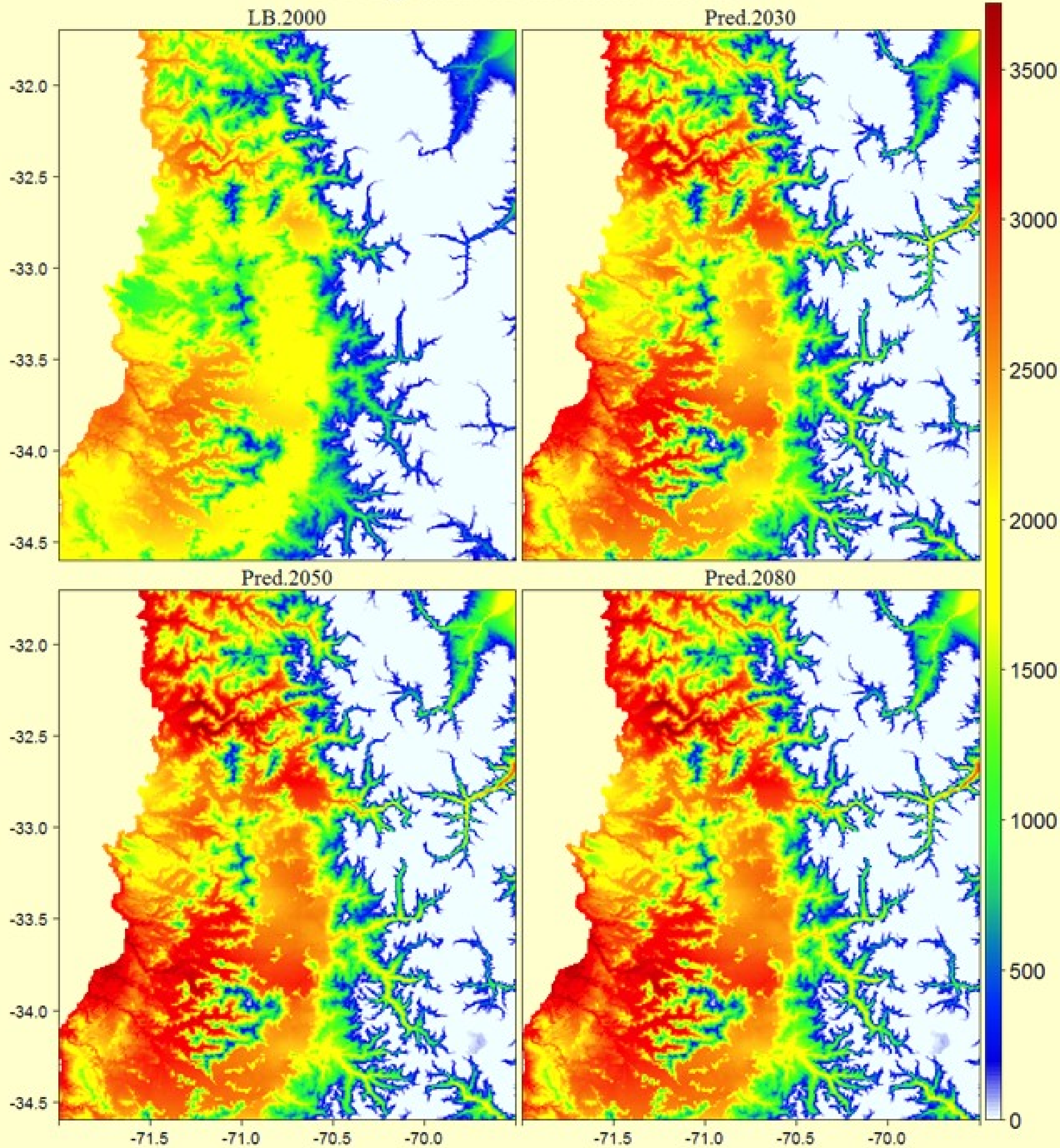


Días grado anual para el escenario rcp6.0




Días grado anual para el escenario rcp8.5
BL2000
X2020
X2030
X2040
X2050
X2060
X2070
X2080
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-71.5
-71.0
-70.5
-70.0
4000
3500
3000
2500
2000
1500
1000
500
0

Días grados acumulados anual



EVAPOTRANSPIRACION (mm/día)

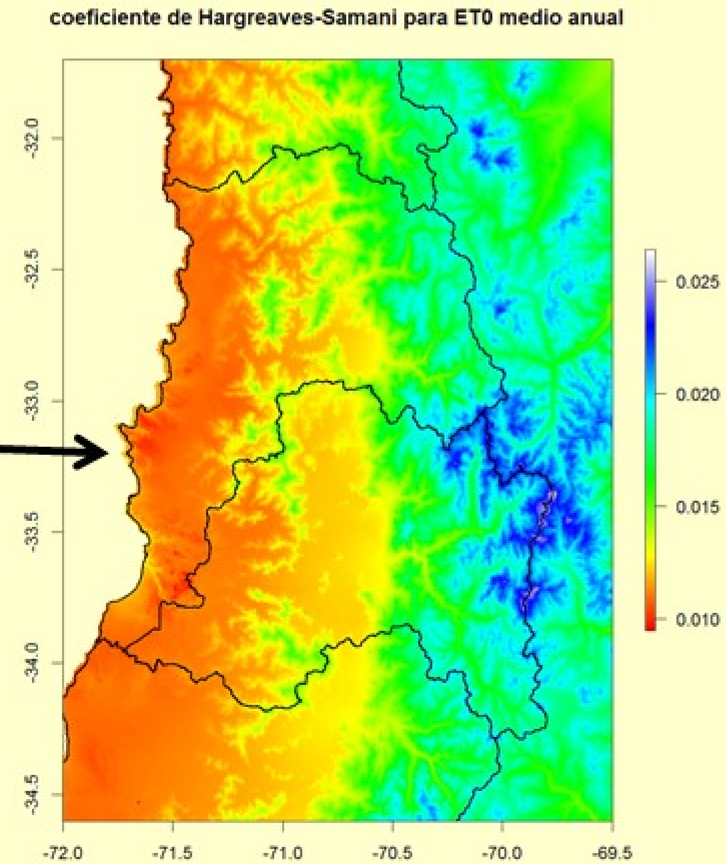
$$ET_d = k_{HS} \cdot \left(\frac{R_g}{\lambda} \right) \cdot \left(T_m + 17.8 \right)$$

$$\lambda = 2.501 - 0.002361 \cdot T_m$$

$$k_{HS} \approx 0.0135$$

$$R_g = k_{RS} \cdot R_{SE} \cdot \sqrt{T_X - T_N}$$

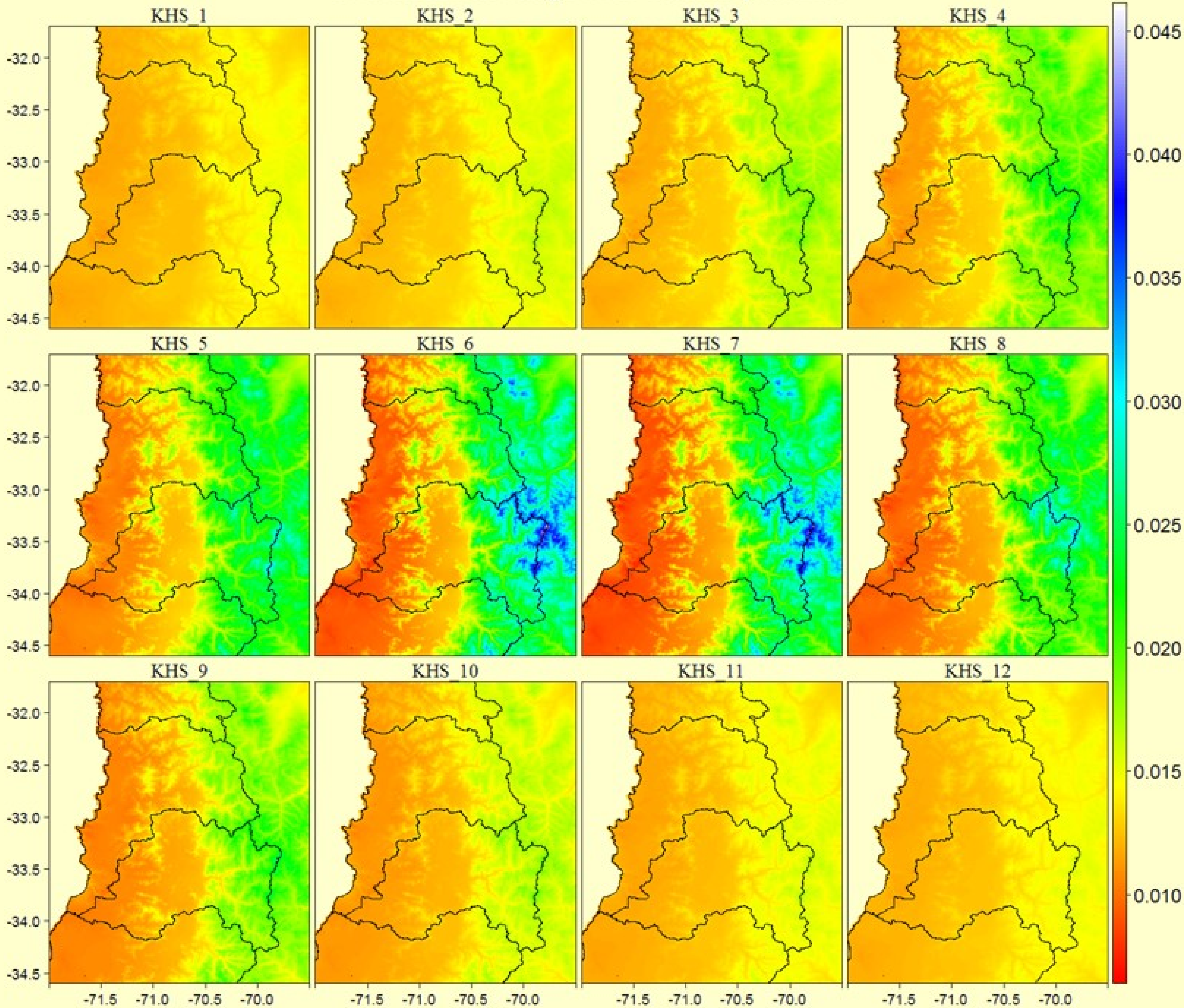
$$k_{RS} \approx 0.17$$



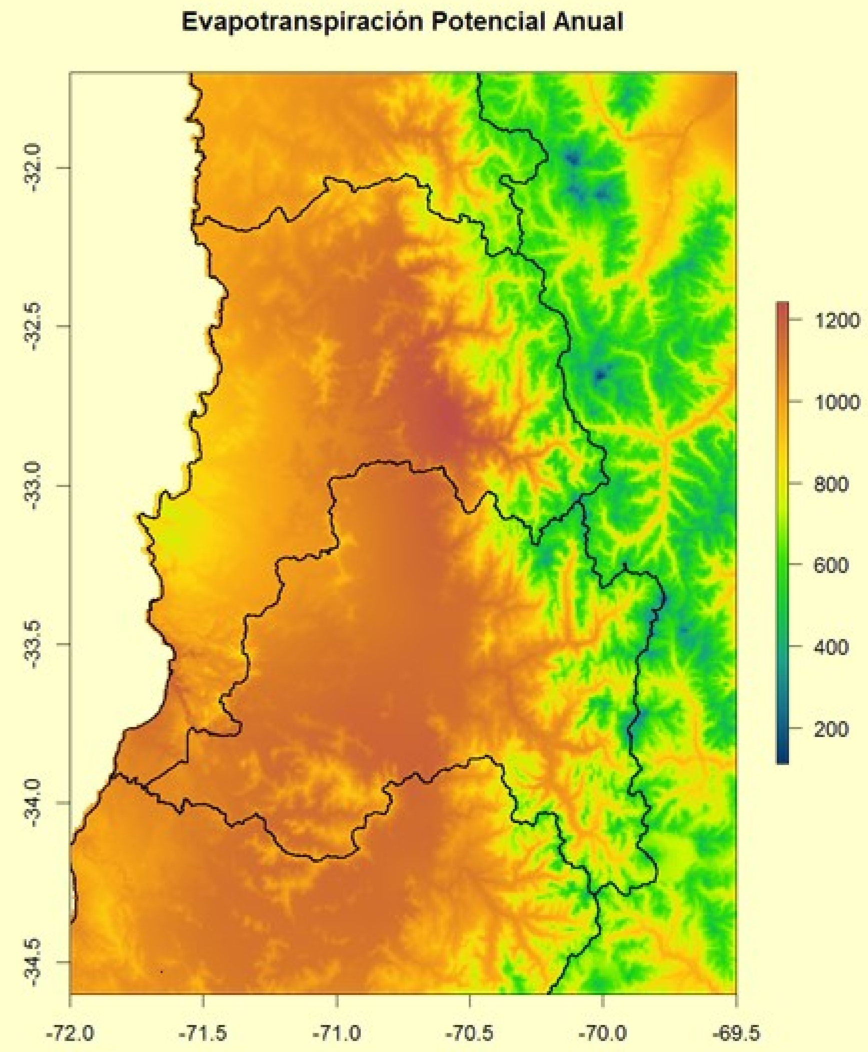
Samani , Z. 2000. Estimating Solar Radiation and Evapotranspiration Using Minimum Climatological Data . Journal of Irrigation and Drainage Engineering, Vol. 126, No. 4, pp. 265-267

Luis Morales-Salinas, Samuel Ortega-Farías, Camilo Riveros-Burgos, José Neira-Román, Marcos Carrasco-Benavides & Rafael López-Olivari. 2017. MONTHLY CALIBRATION OF HAR-GREAVES–SAMANI EQUATION USING REMOTE SENSING AND TOPOCLIMATOLOGY IN CENTRAL-SOUTHERN CHILE. International Journal of Remote Sensing (ISI), https://doi.org/10.1080/01431161.2017.1323287.

coeficiente de Hargreaves-Samani para ET0

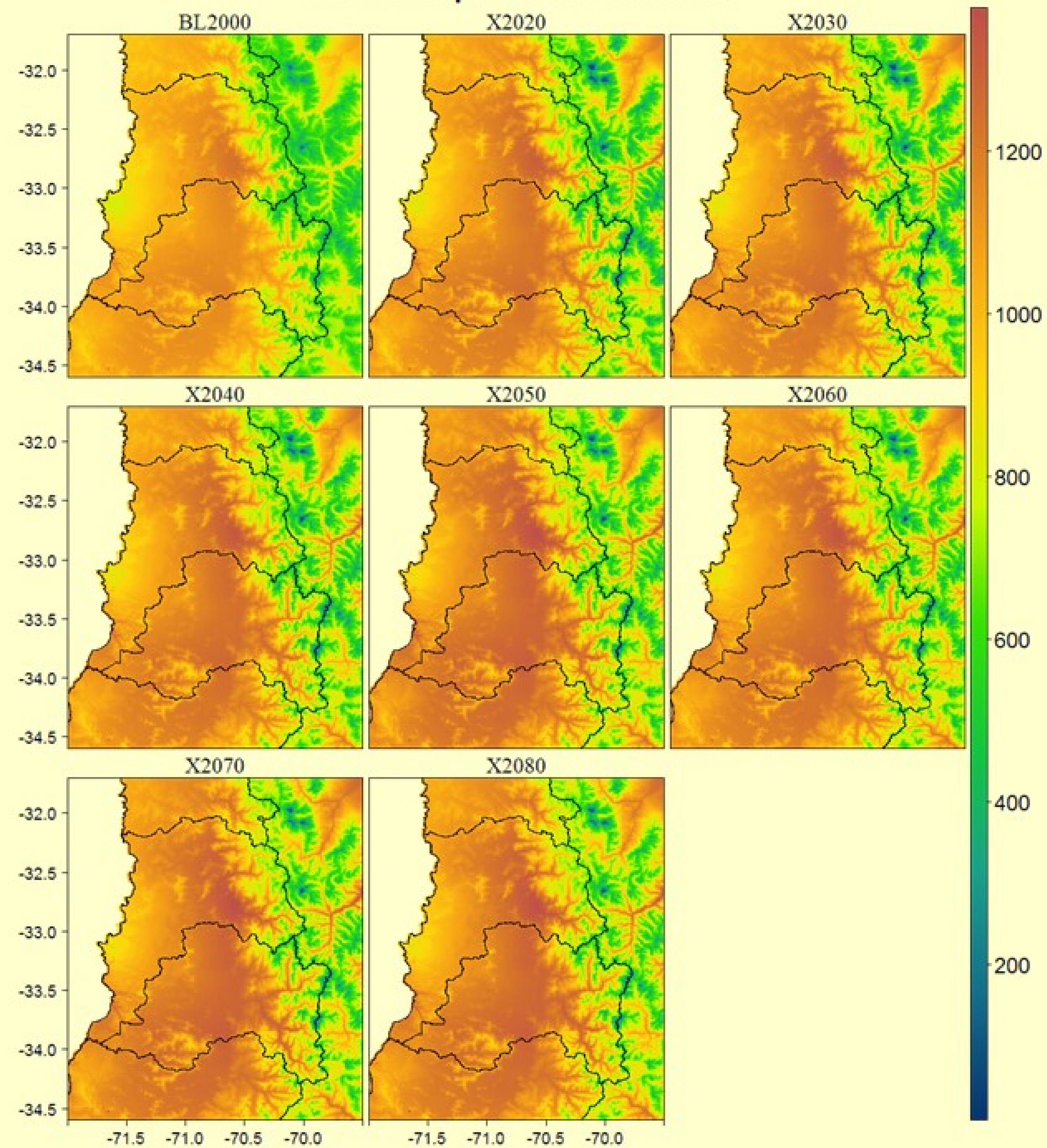


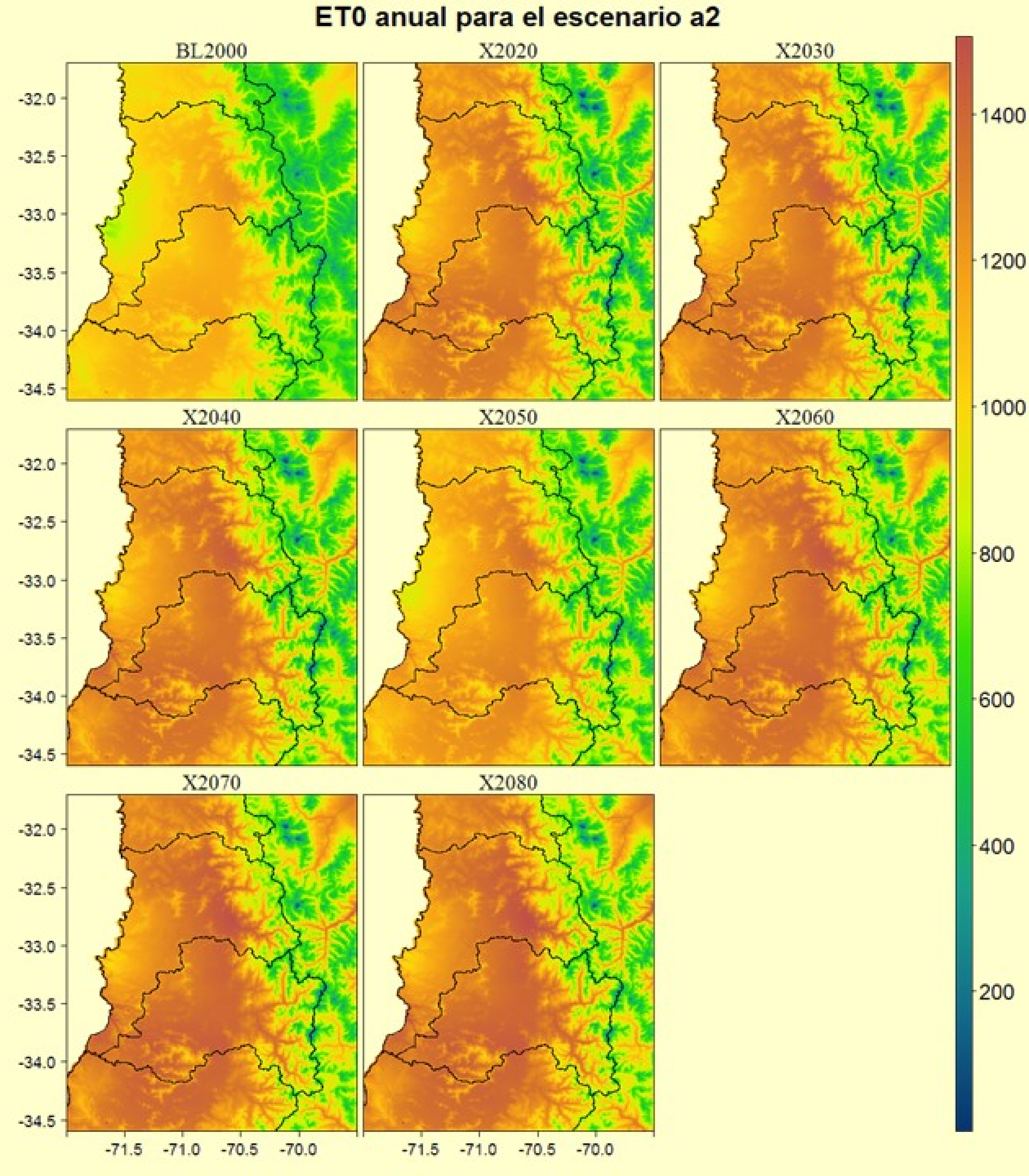
ETo



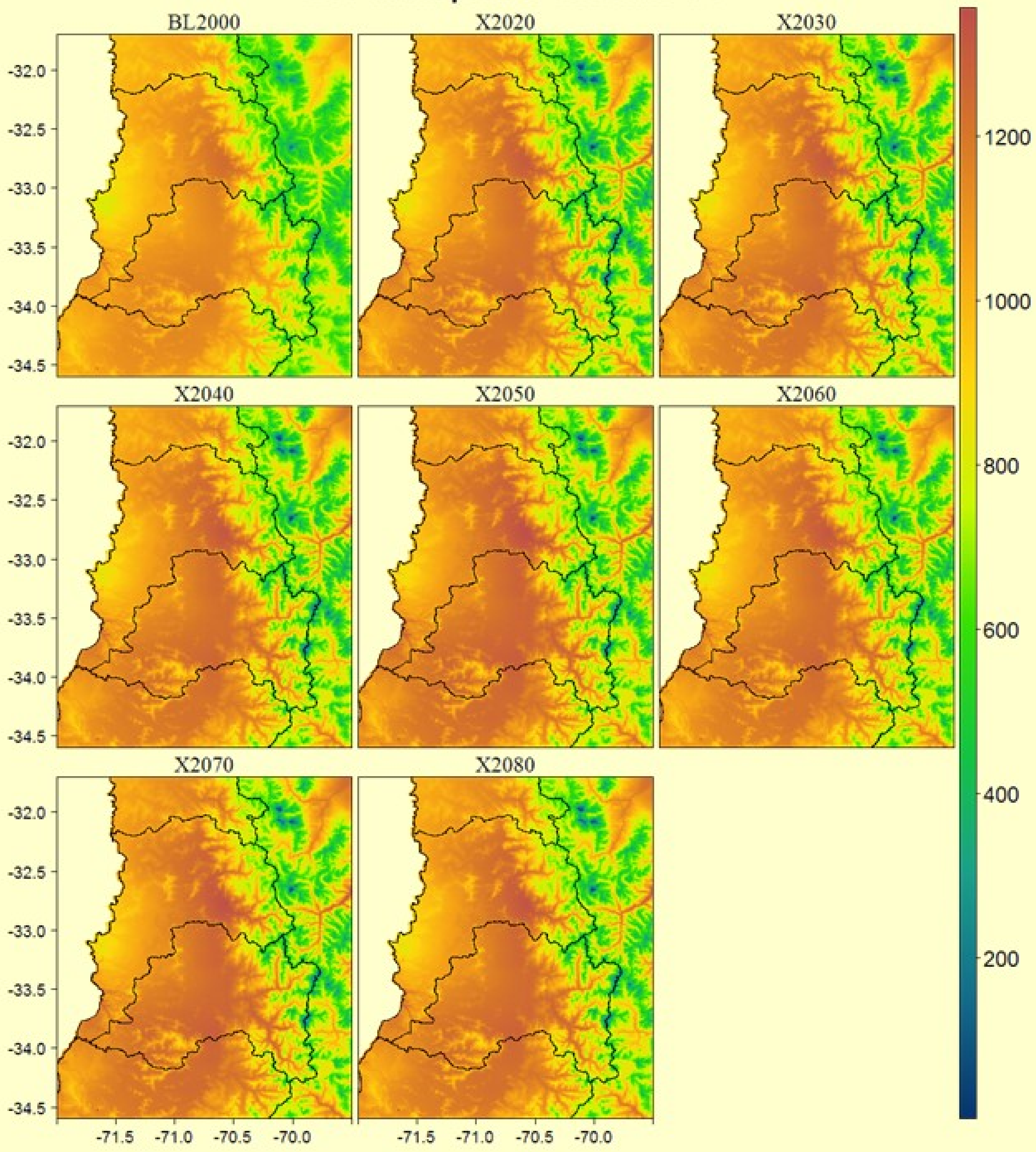
Evapotranspiración Potencial Anual
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-72.0
-71.5
-71.0
-70.5
-70.0
-69.5
1200
1000
800
600
400
200

ET0 anual para el escenario a1b

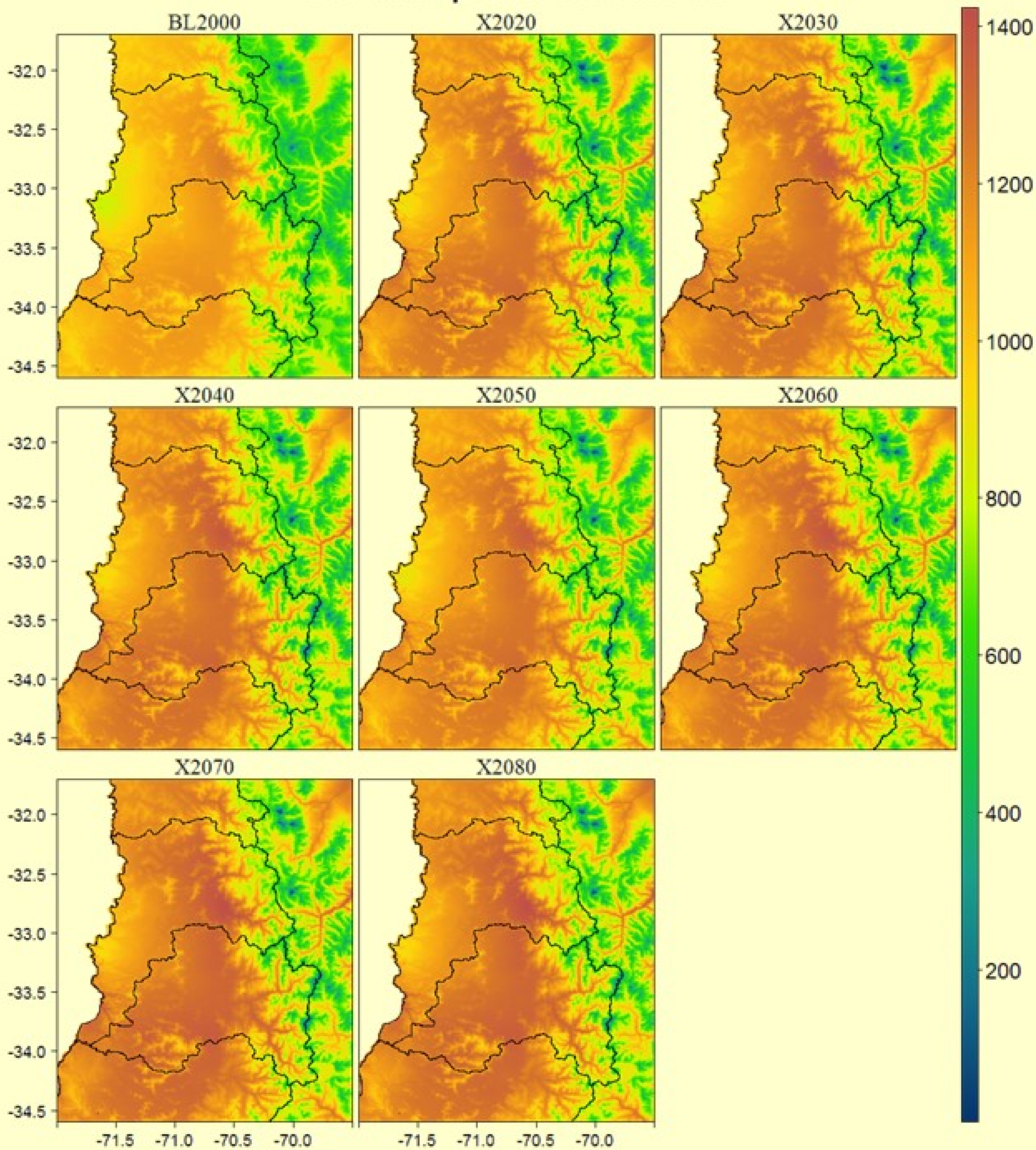



ET0 anual para el escenario a2
BL2000
X2020
X2030
X2040
X2050
X2060
X2070
X2080
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-71.5
-71.0
-70.5
-70.0
1400
1200
1000
800
600
400
200

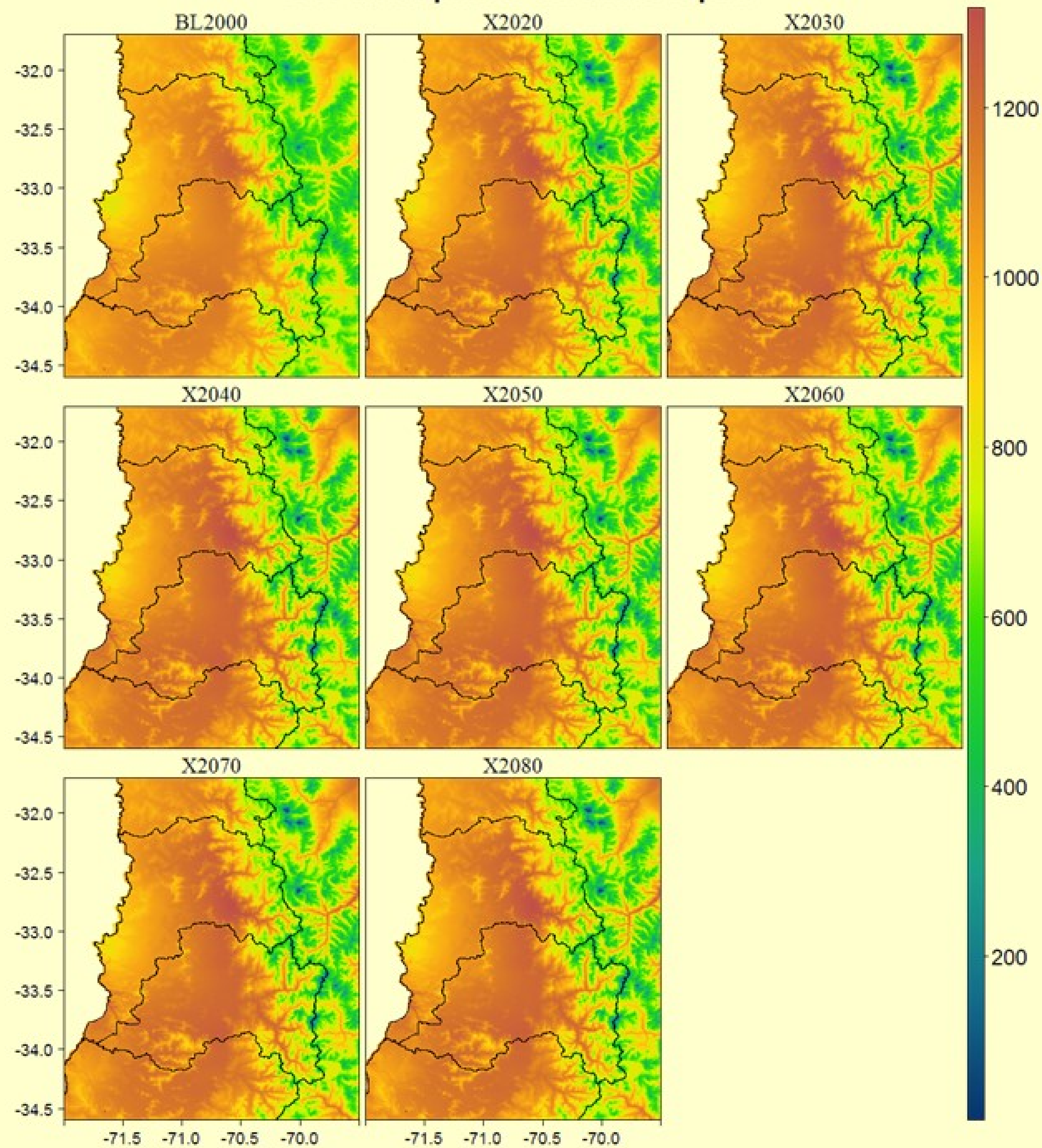
ET0 anual para el escenario b1



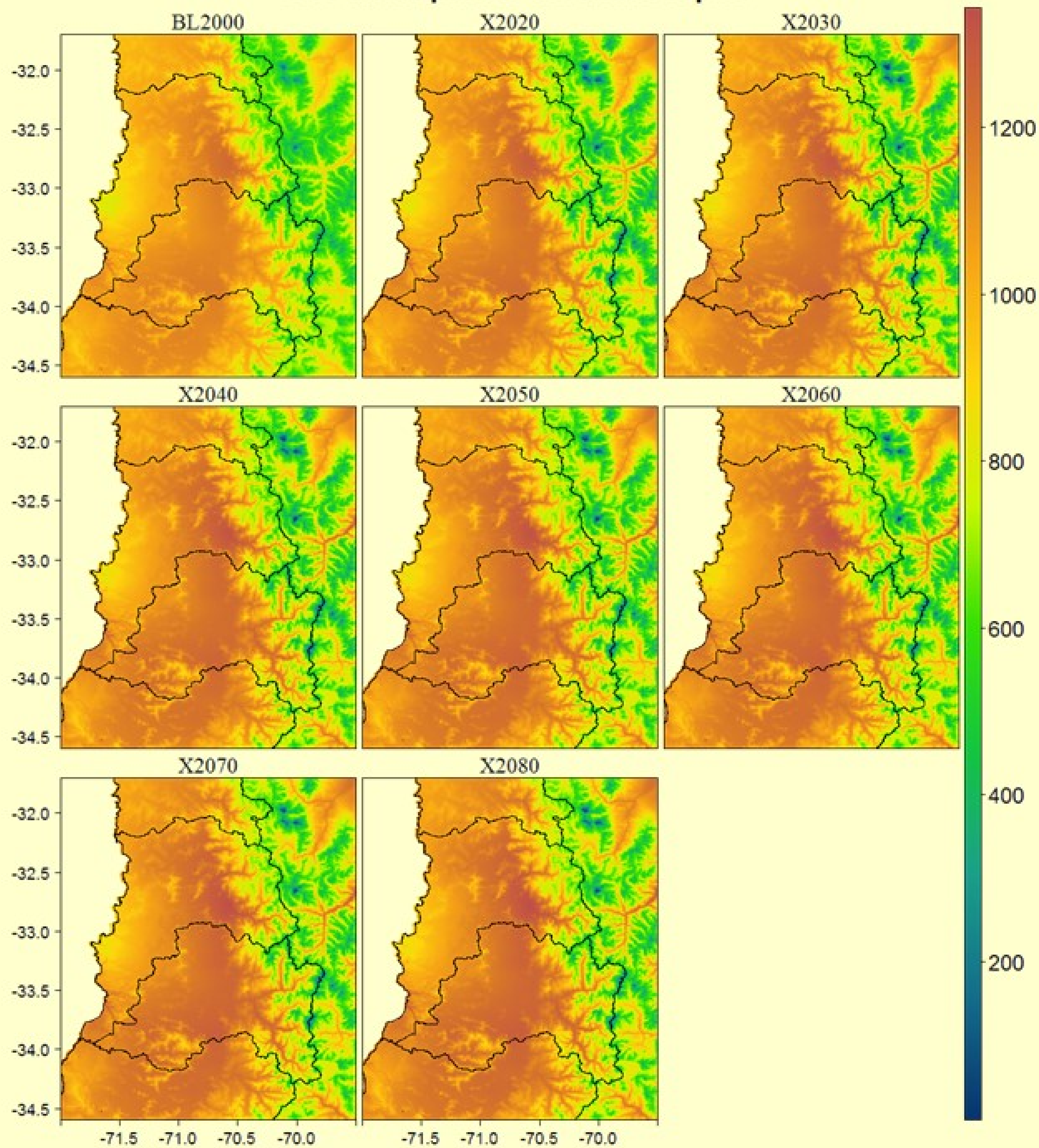
ET0 anual para el escenario b2



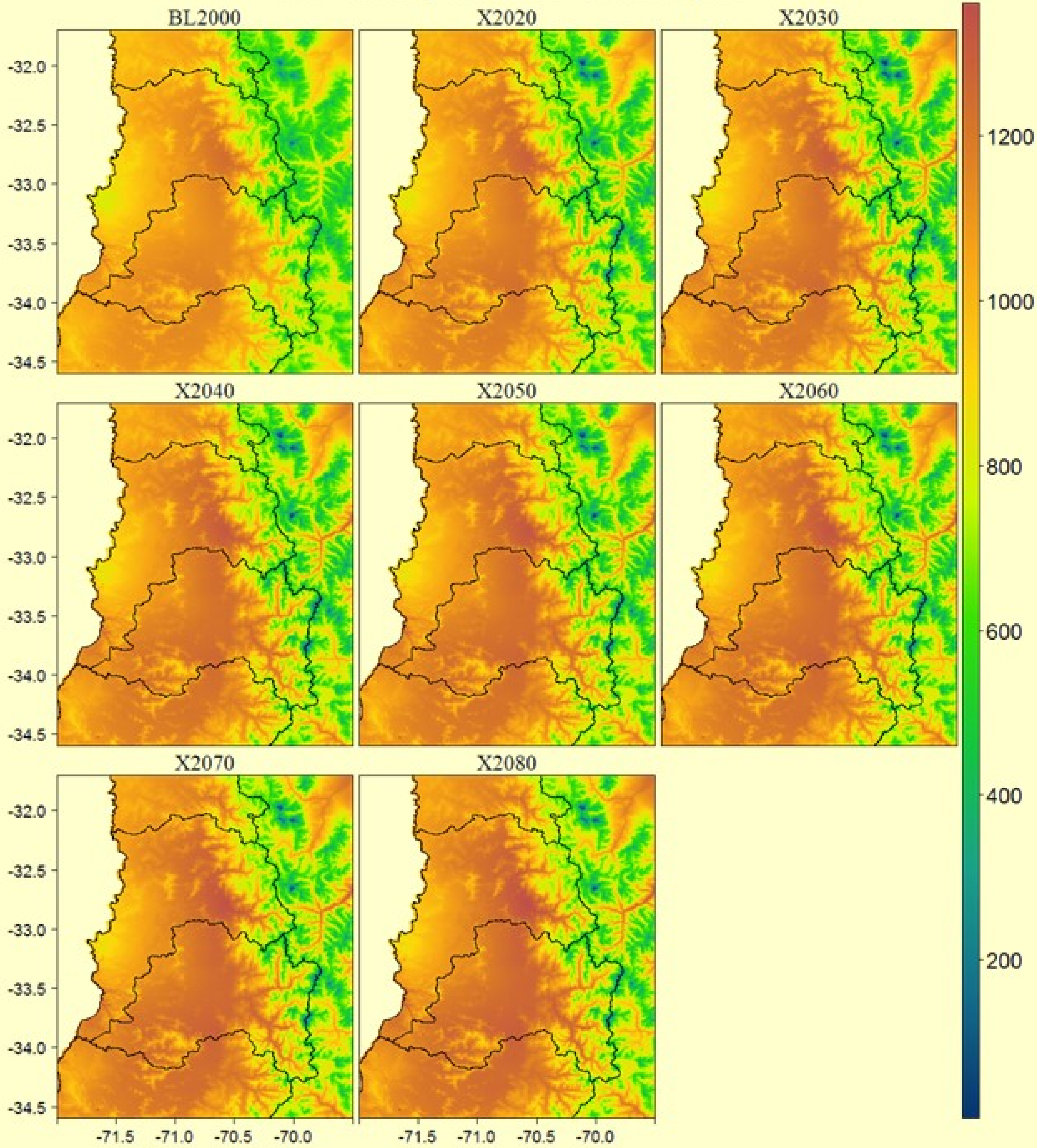
ET0 anual para el escenario rcp2.6



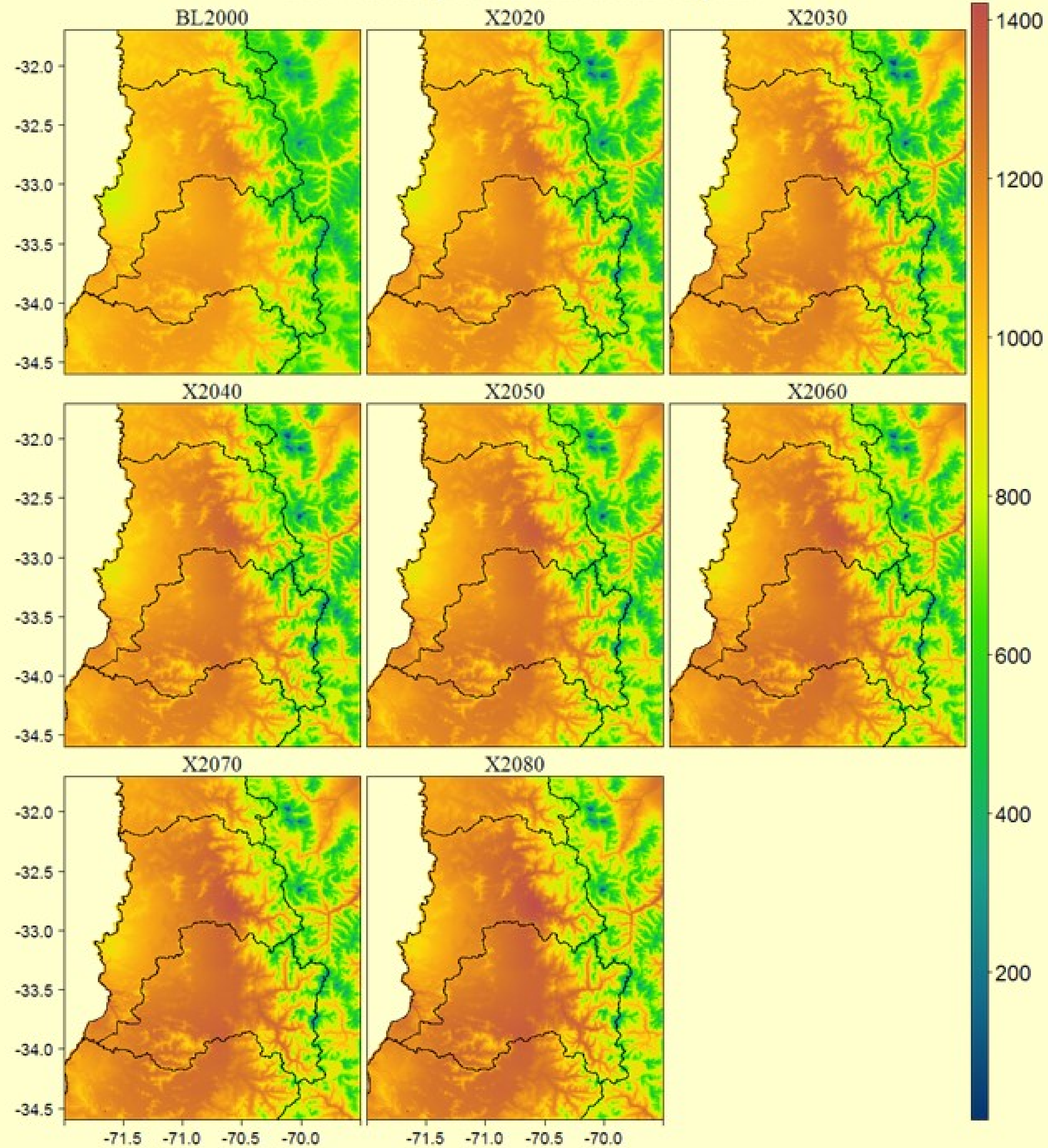
ET0 anual para el escenario rcp4.5



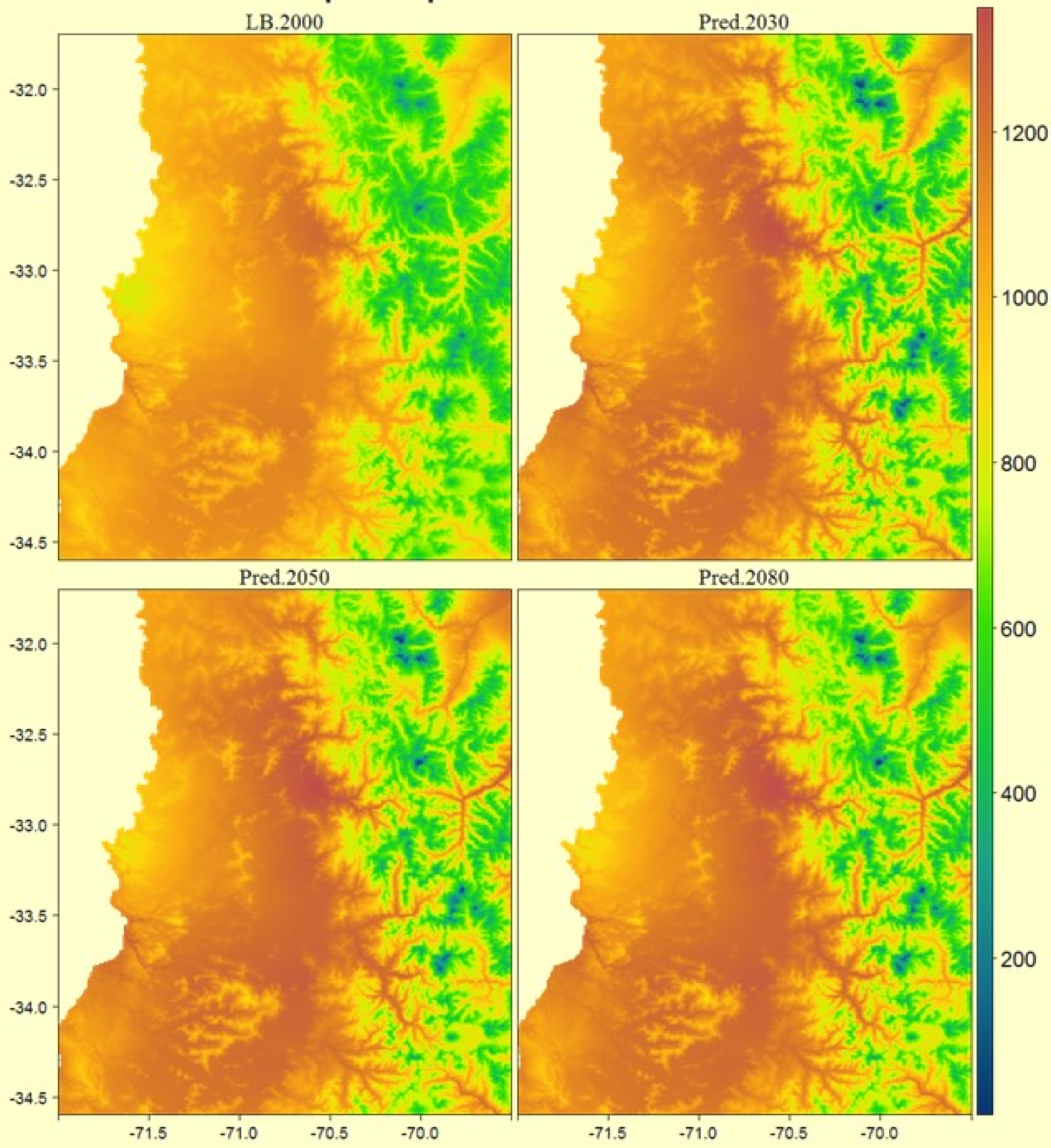
ET0 anual para el escenario rcp6.0



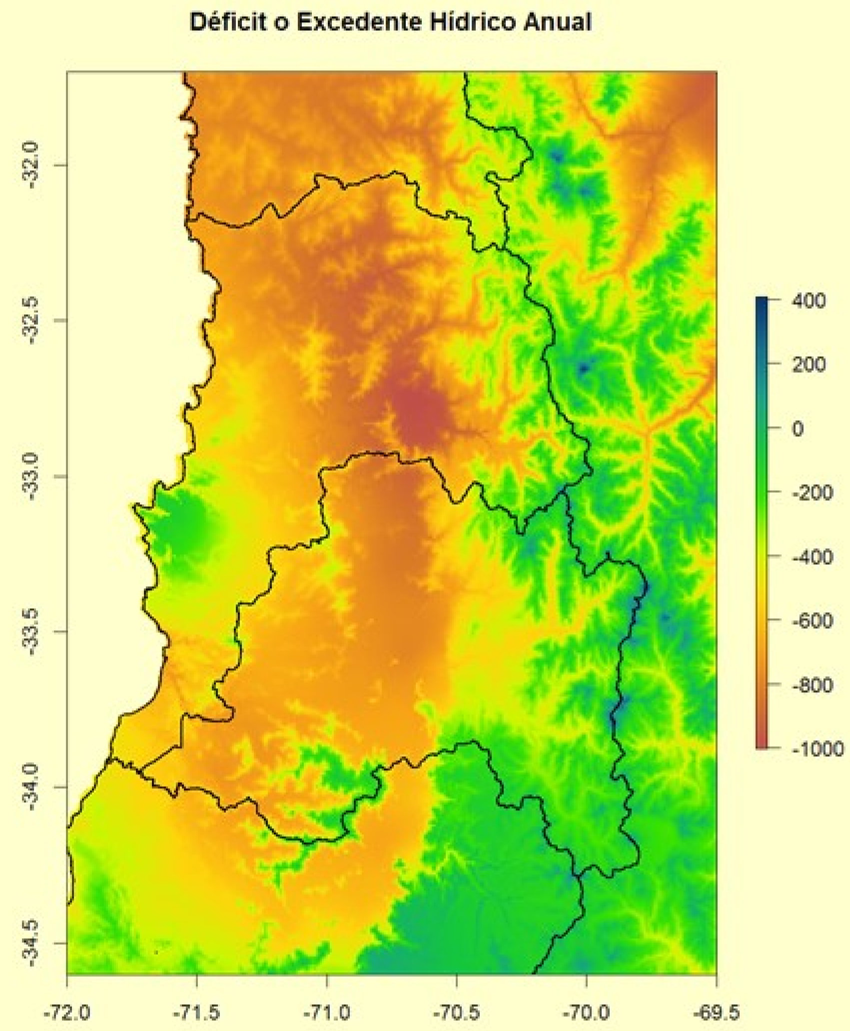
ET0 anual para el escenario rcp8.5



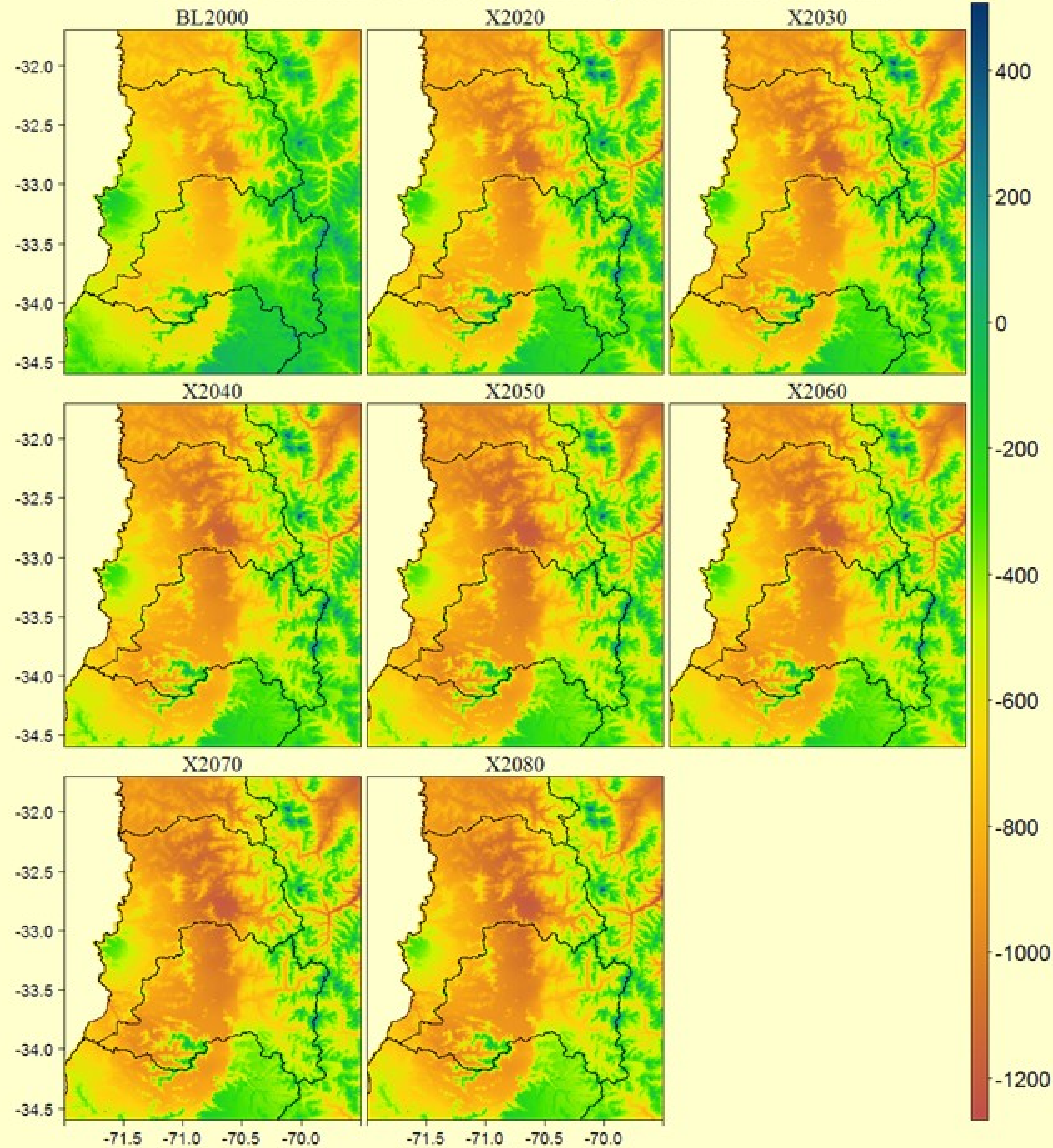
Evapotranspiración acumulada anual



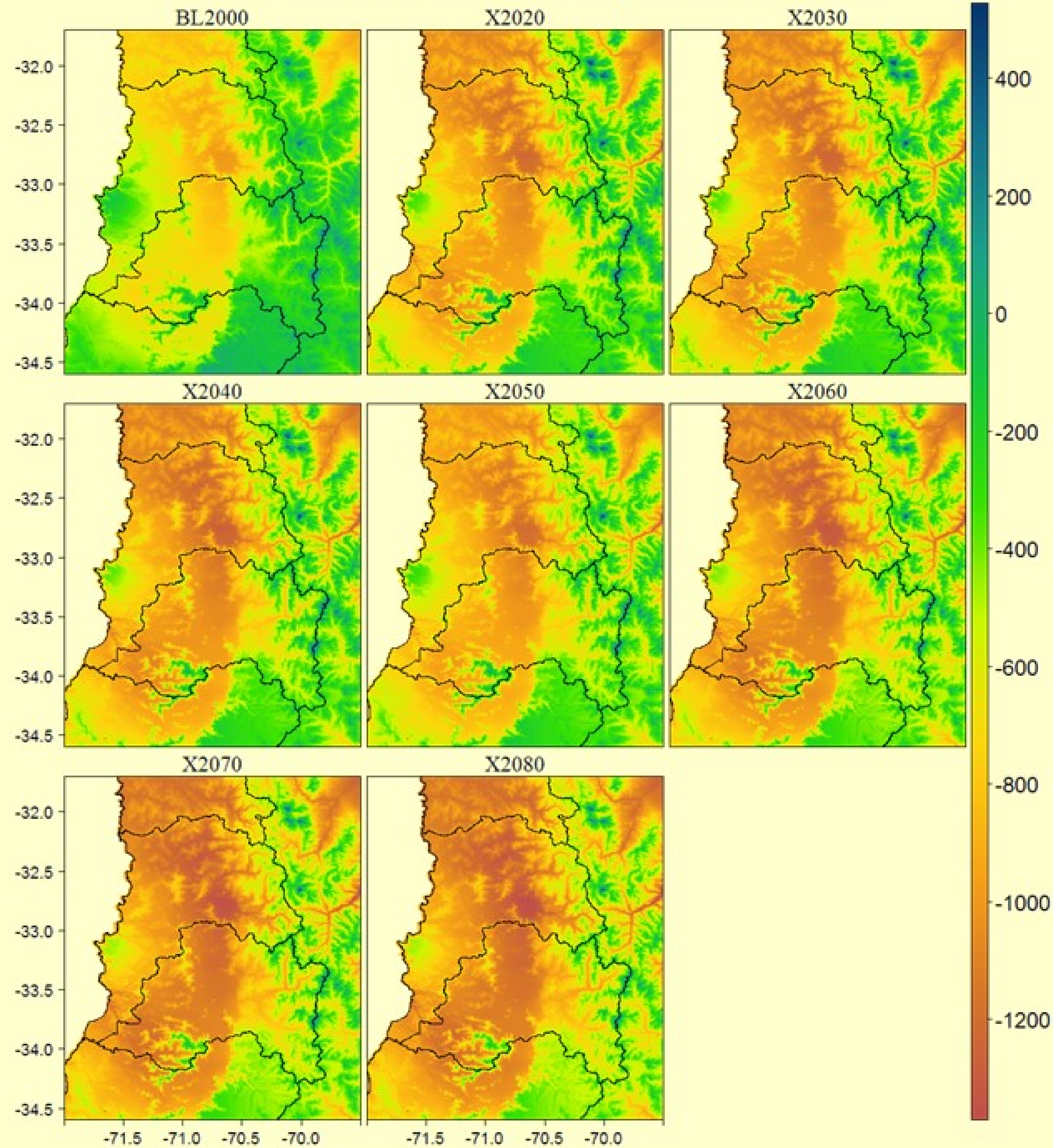
BALANCE HIDRICO



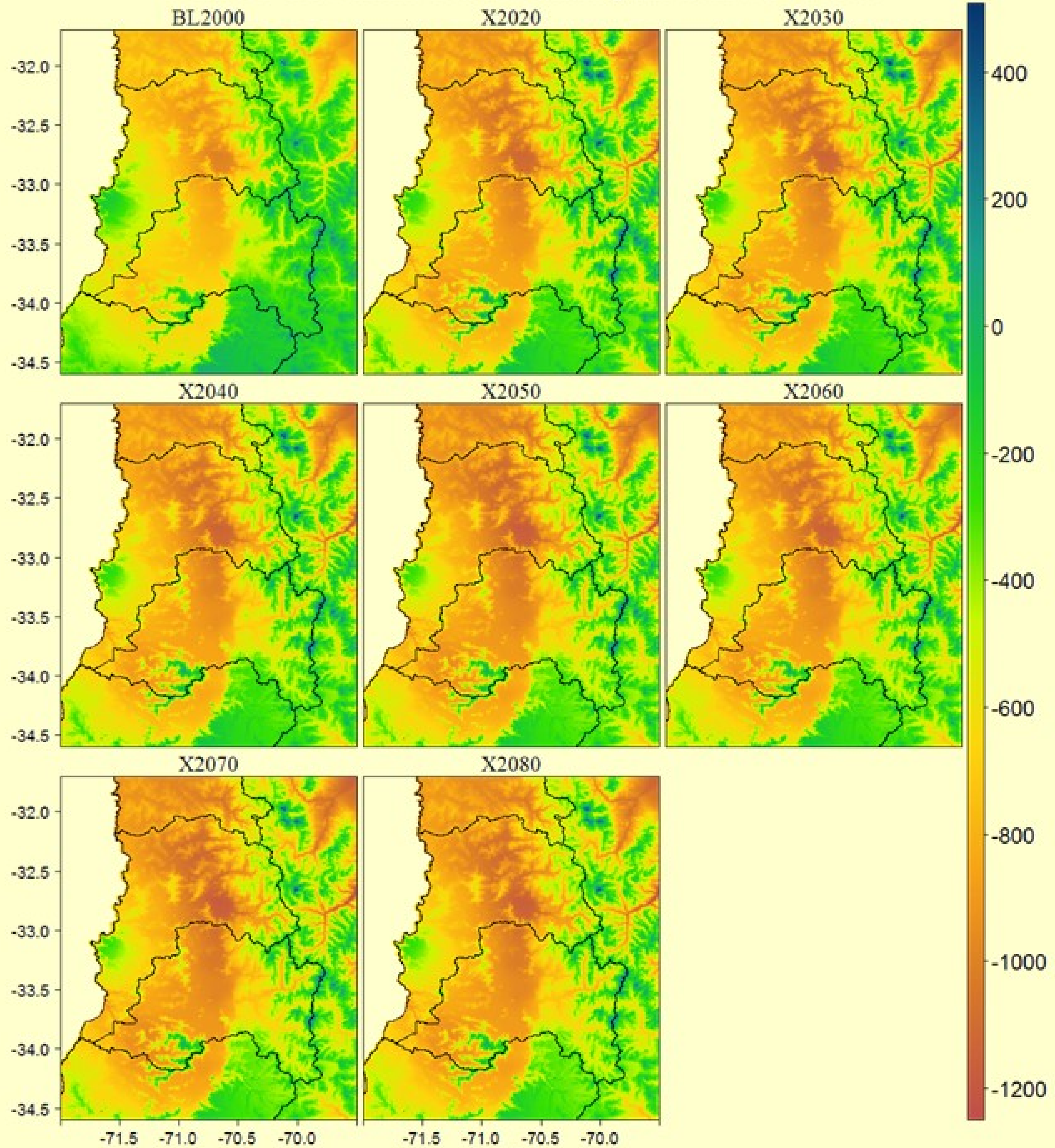
Déficit o excedente hídrico anual para el escenario a1b



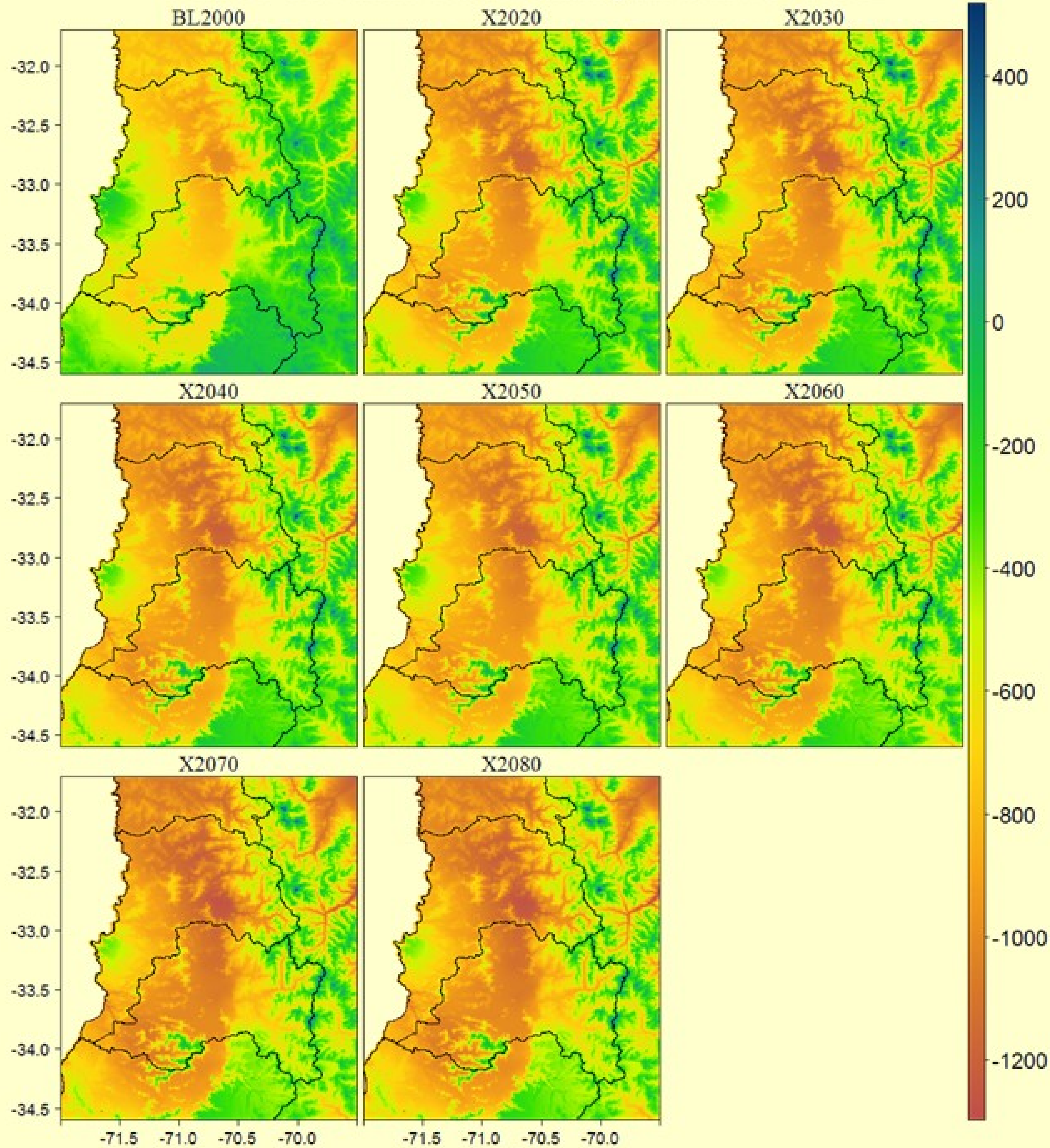
Déficit o excedente hídrico anual para el escenario a2

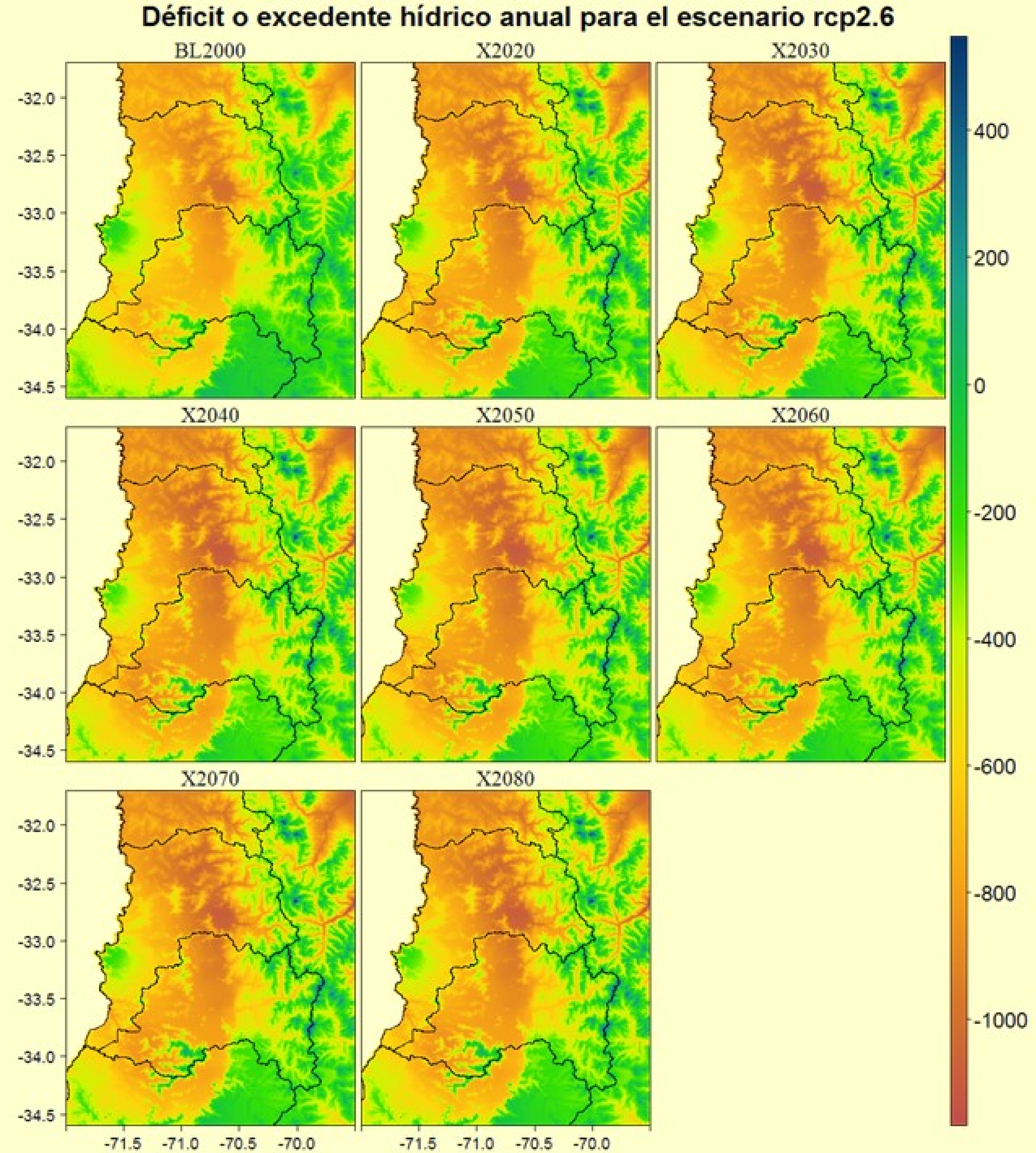


Déficit o excedente hídrico anual para el escenario b1



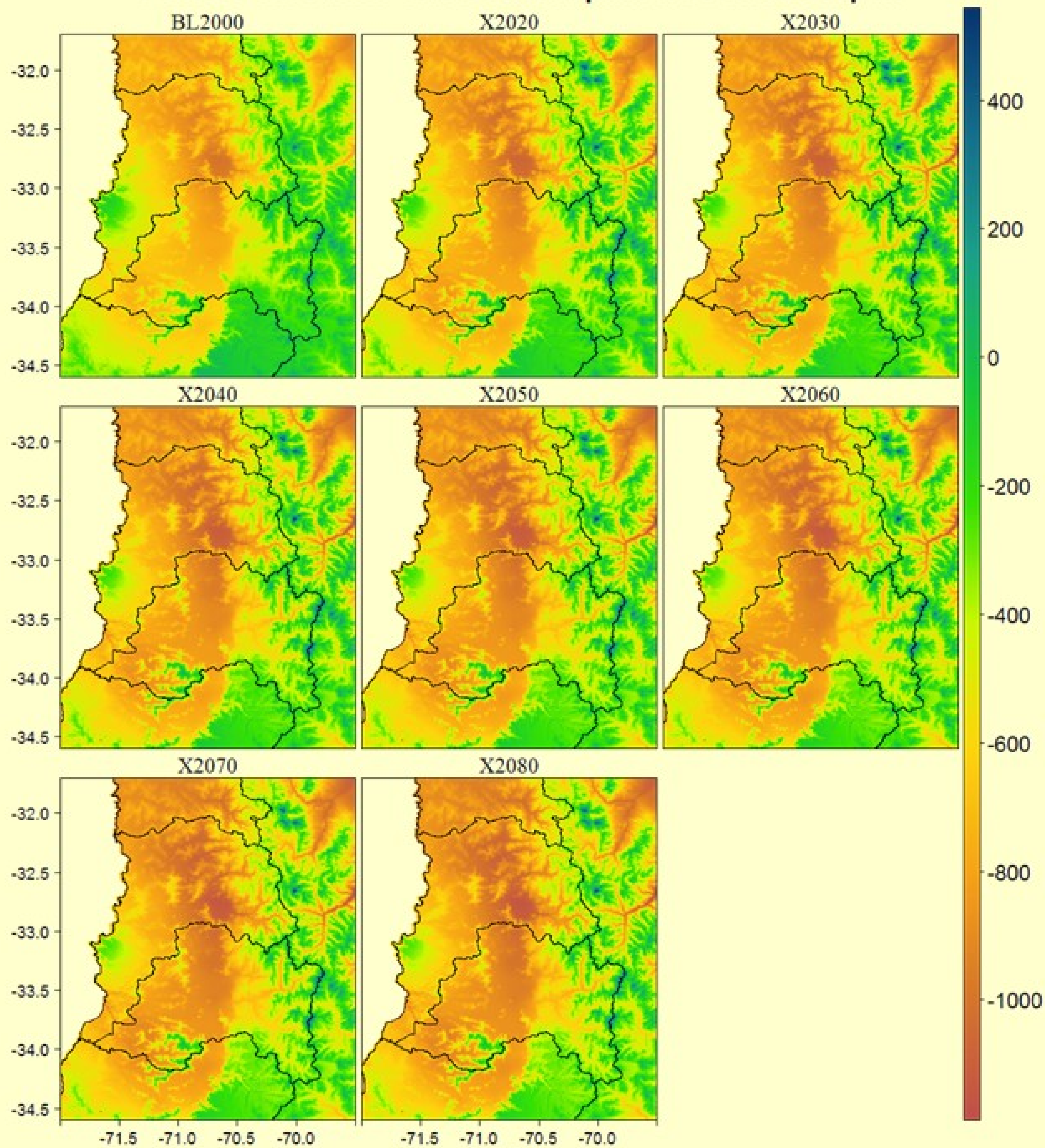
Déficit o excedente hídrico anual para el escenario b2

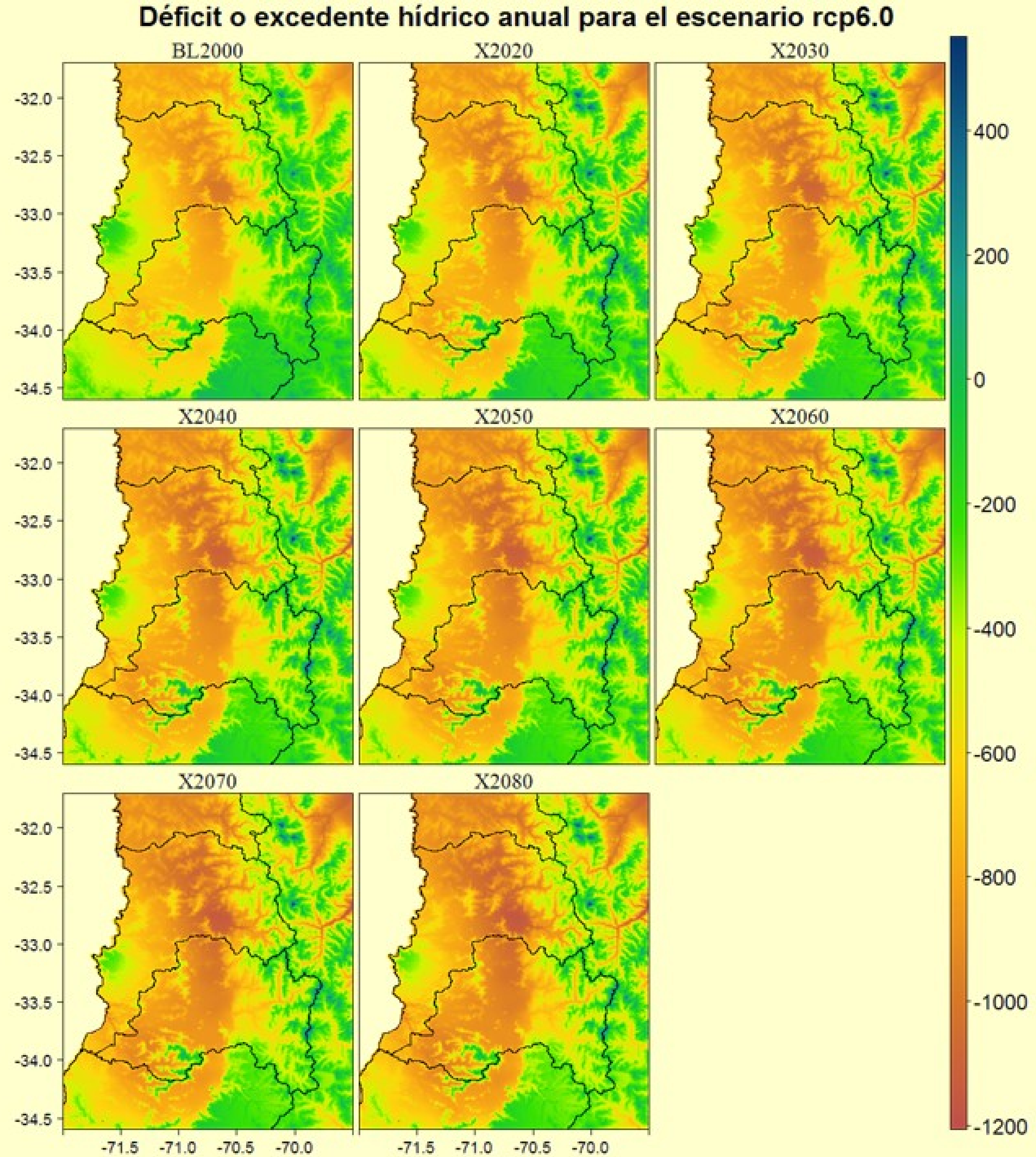




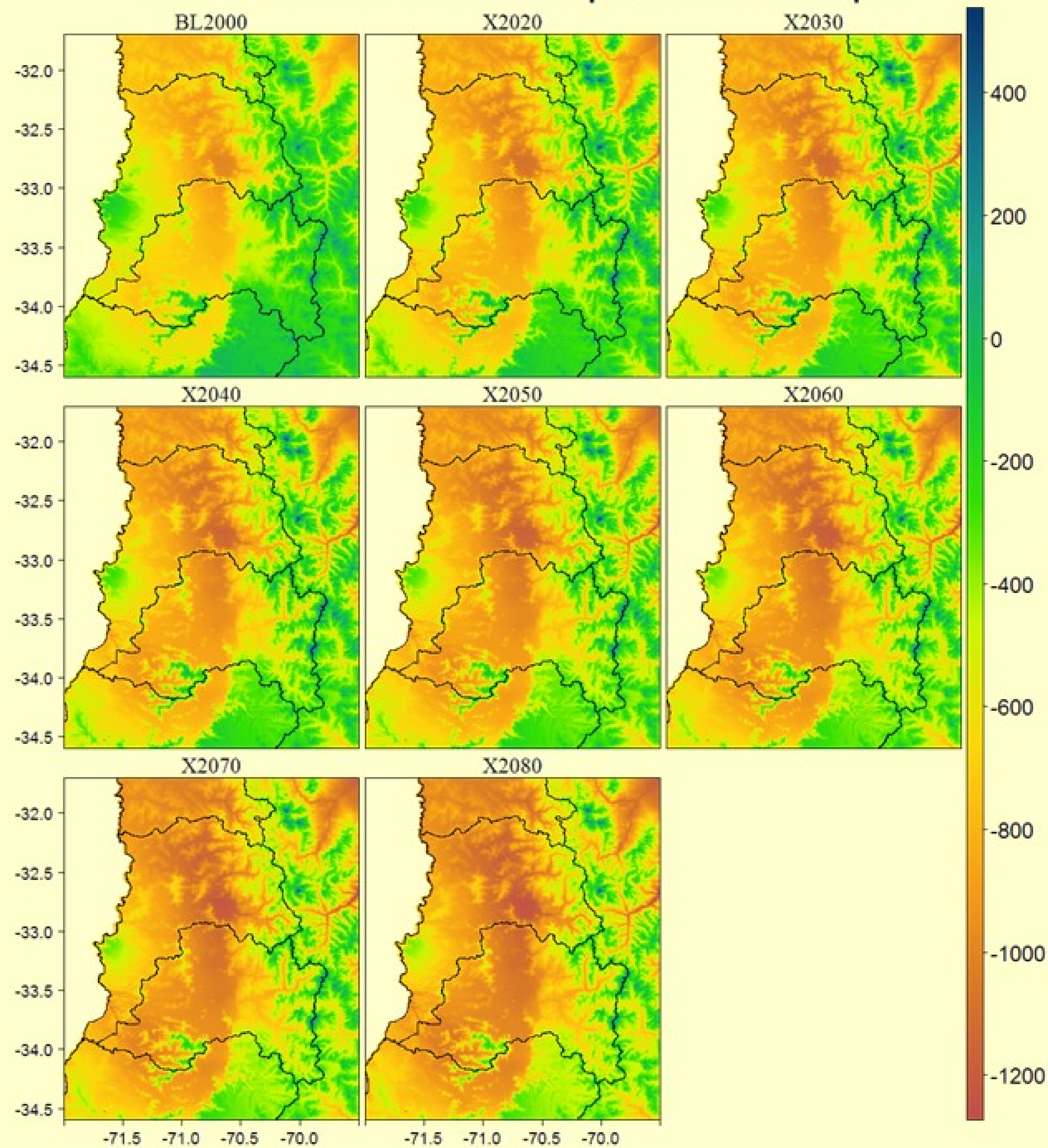
Déficit o excedente hídrico anual para el escenario rcp2.6
BL2000
X2020
X2030
X2040
X2050
X2060
X2070
X2080
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-71.5
-71.0
-70.5
-70.0
400
200
0
-200
-400
-600
-800
-1000

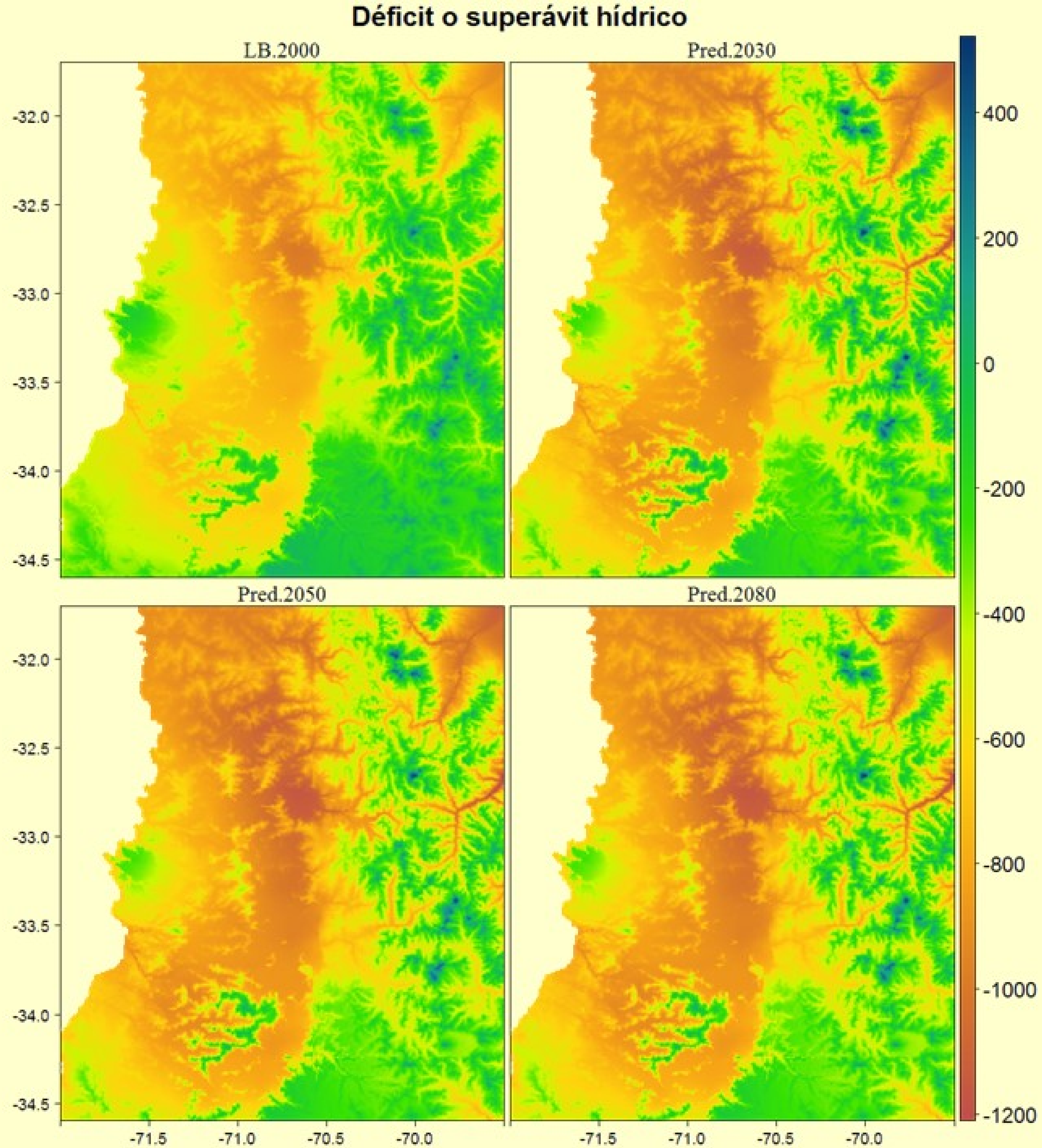
Déficit o excedente hídrico anual para el escenario rcp4.5




Déficit o excedente hídrico anual para el escenario rcp6.0
BL2000
X2020
X2030
X2040
X2050
X2060
X2070
X2080
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-71.5
-71.0
-70.5
-70.0
400
200
0
-200
-400
-600
-800
-1000
-1200

Déficit o excedente hídrico anual para el escenario rcp8.5





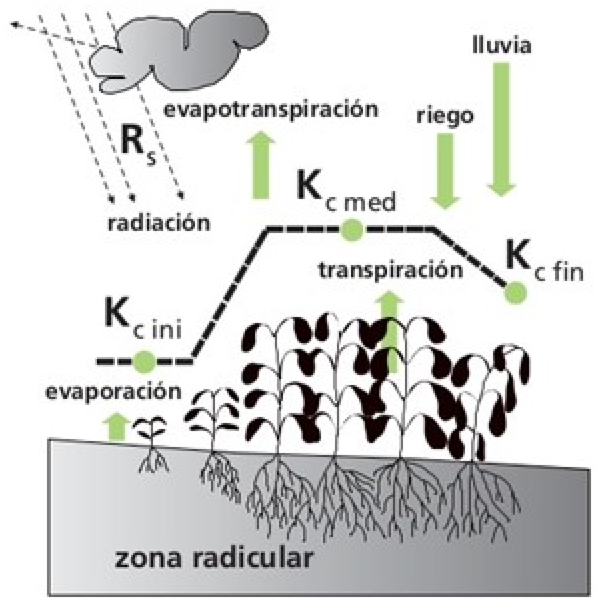
Déficit o superávit hídrico
LB.2000
Pred.2030
Pred.2050
Pred.2080
-32.0
-32.5
-33.0
-33.5
-34.0
-34.5
-71.5
-71.0
-70.5
-70.0
400
200
0
-200
-400
-600
-800
-1000
-1200

ESTUDIO FAO
RIEGO Y
DRENAJE

56

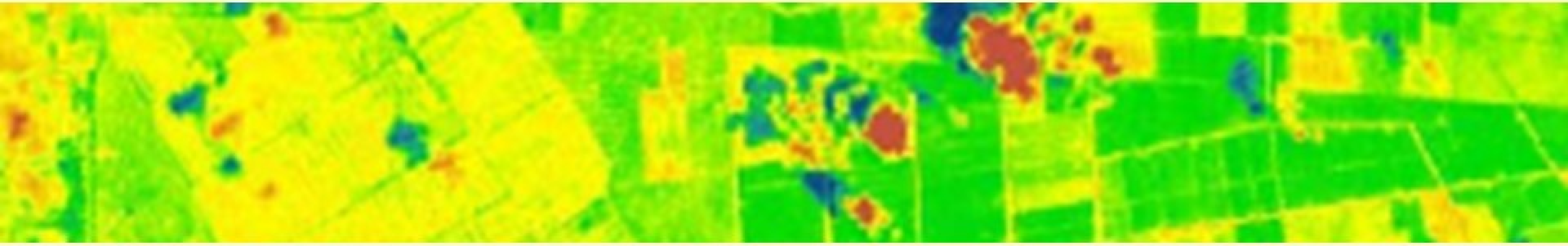
Evapotranspiración del cultivo

Guías para la determinación de los requerimientos de agua de los cultivos



ETo

- Mediciones in situ
- Modelos teóricos
- Modelación de mesoescala
- Métodos semi-empíricos
- Teledetección
- Hibridaciones varias



Parsimonia ?

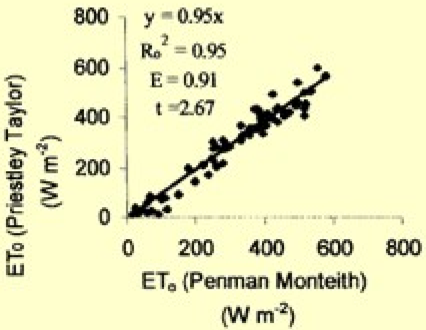
Entenderemos este concepto asociado al principio de simplicidad de Newton: "Porque a la naturaleza le complace la sencillez, y no gusta de la pompa de las causas superfluas"

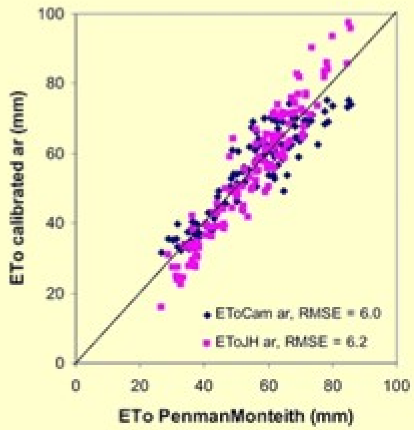
o bien preferiremos de entre un zoológico de alternativas teóricas, empíricas y semiempíricas el modelo más simple posible entre varias alternativas (Se considera un principio heurístico típico de la ciencia moderna).

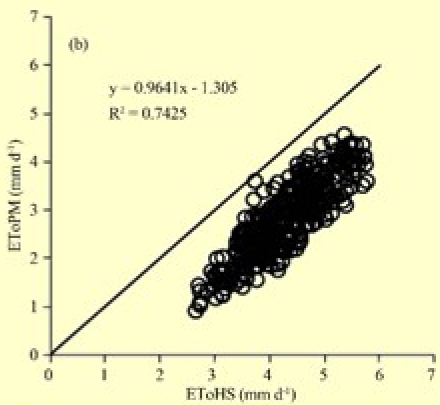
Métodos Simples

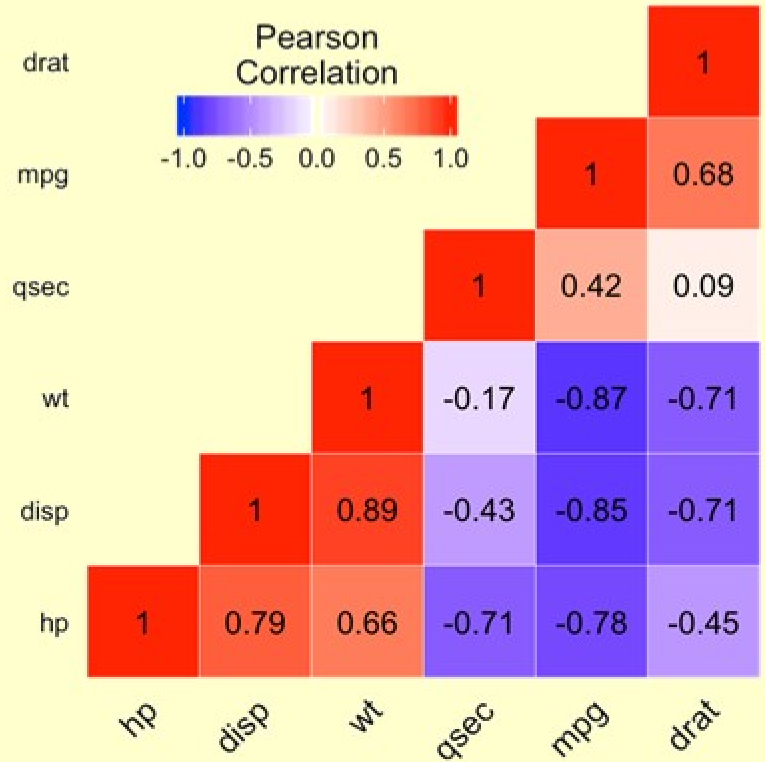
- Lisímetro
- Bandeja
- Ivanov
- Papadakis
- Blanney y Criddle
- Blanney-Morin
- Hargreaves-Samani
- Turc
- Jensen-Haise
- Makkink
- Priestley-Taylor
- Penman-Monteith

Estos métodos están correlacionados

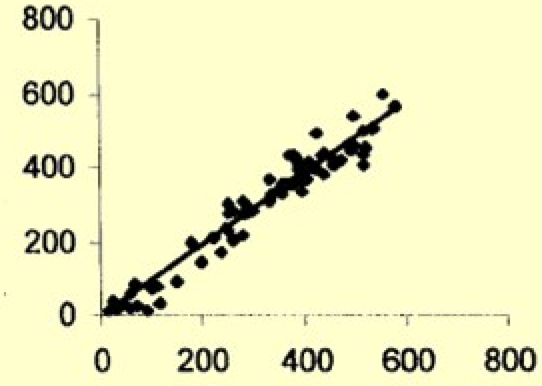








Penman-Monteith

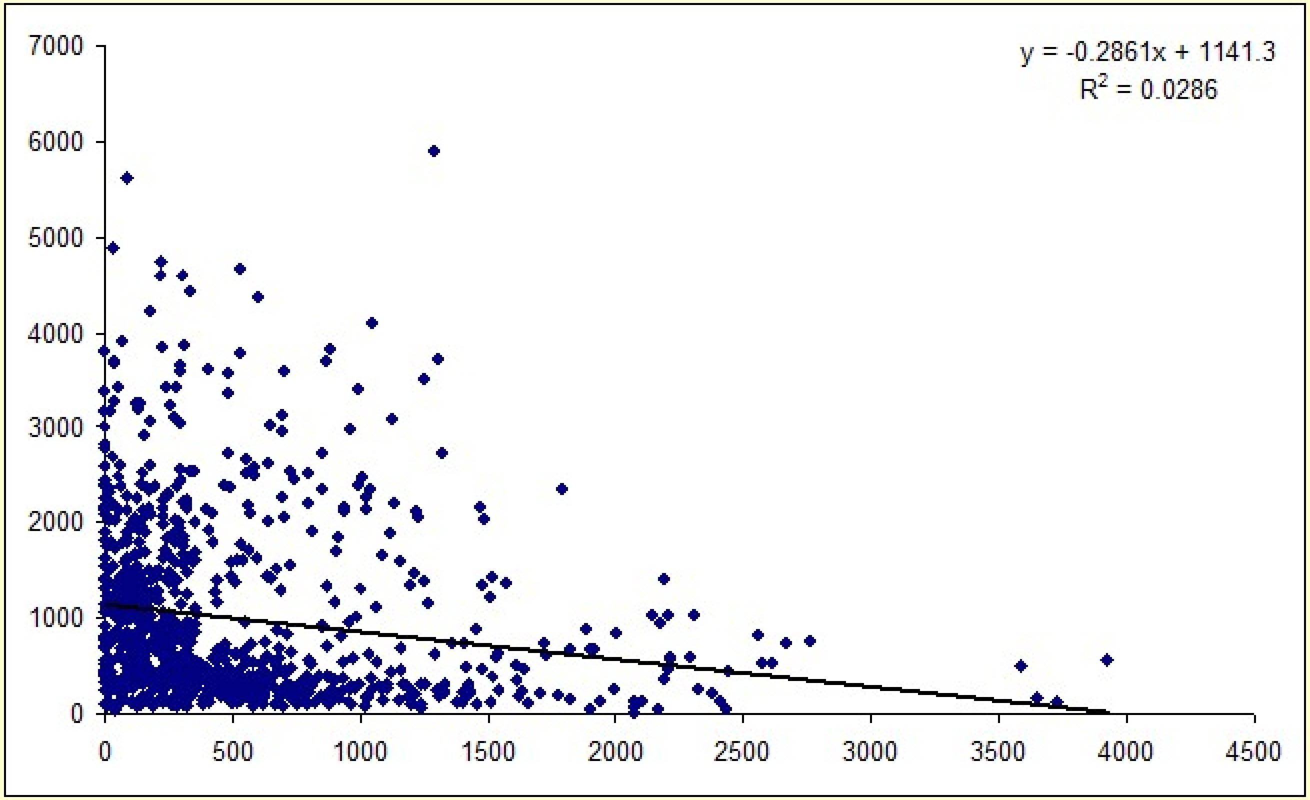


Otros

$$\frac{Penman - Monteith}{Otros} = Función \;\; Corrección \;\; (Var.\,Amb.)$$

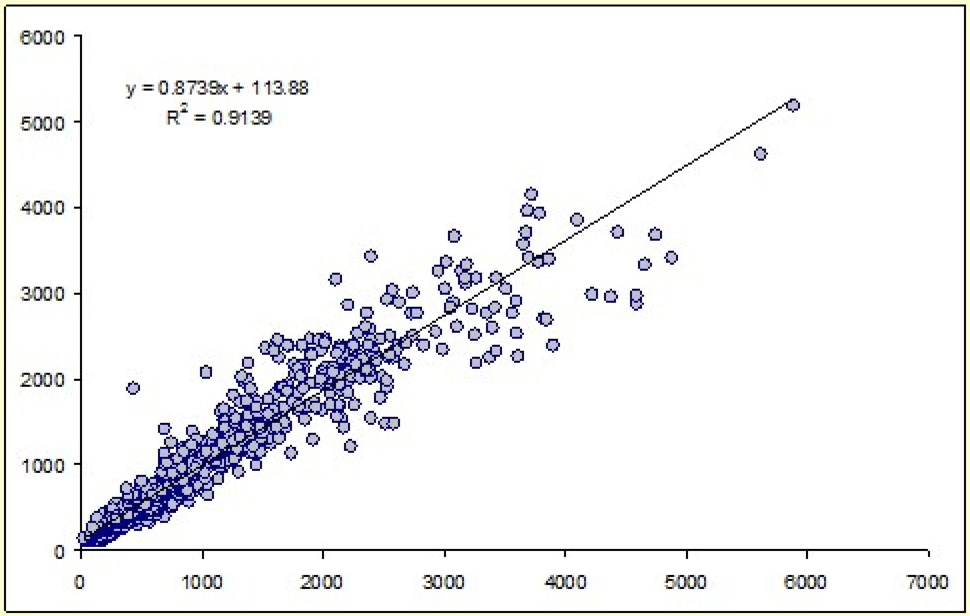
PRECIPITACION ANUAL

$$PPMA = a + b \cdot ALT$$



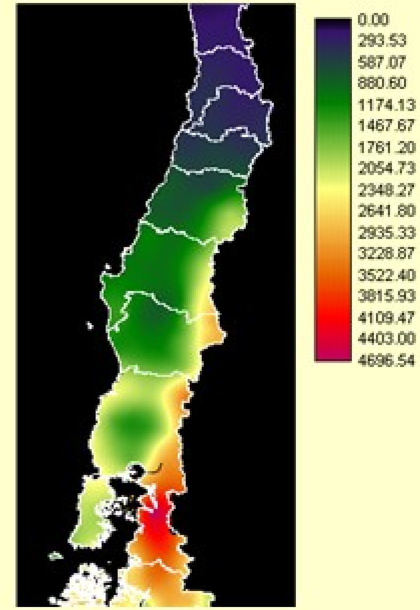
PRECIPITACION ANUAL

Topoclimático

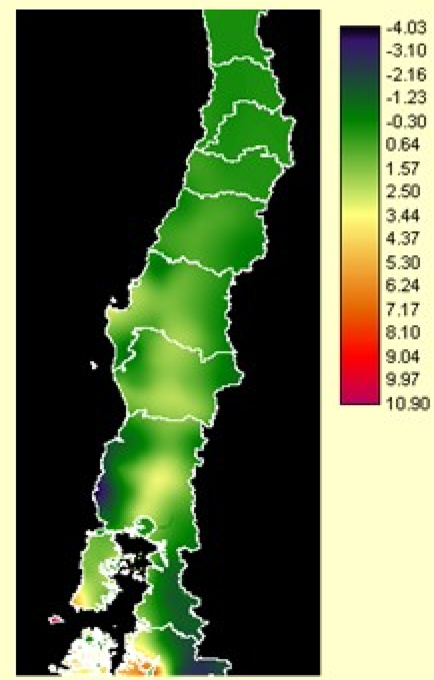


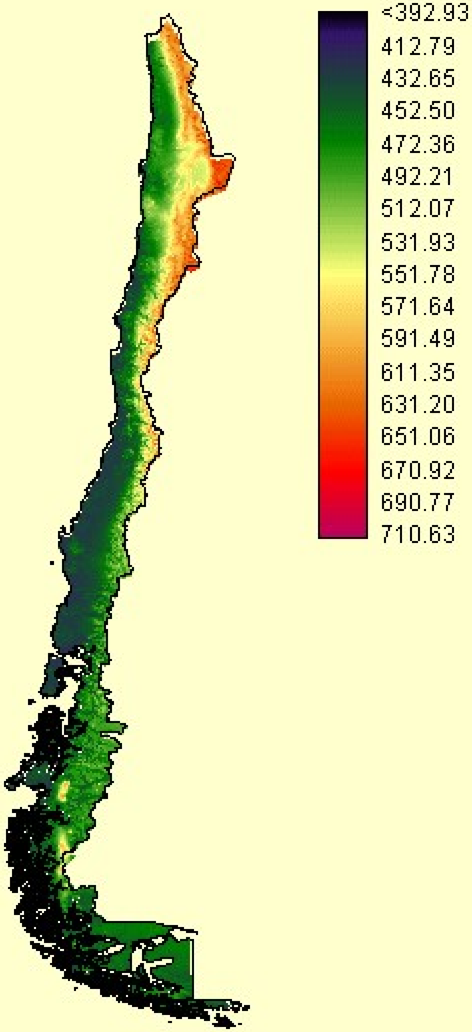
$$PPMA = a(x,y) + b(x,y) \cdot ALT$$

a(x,y)

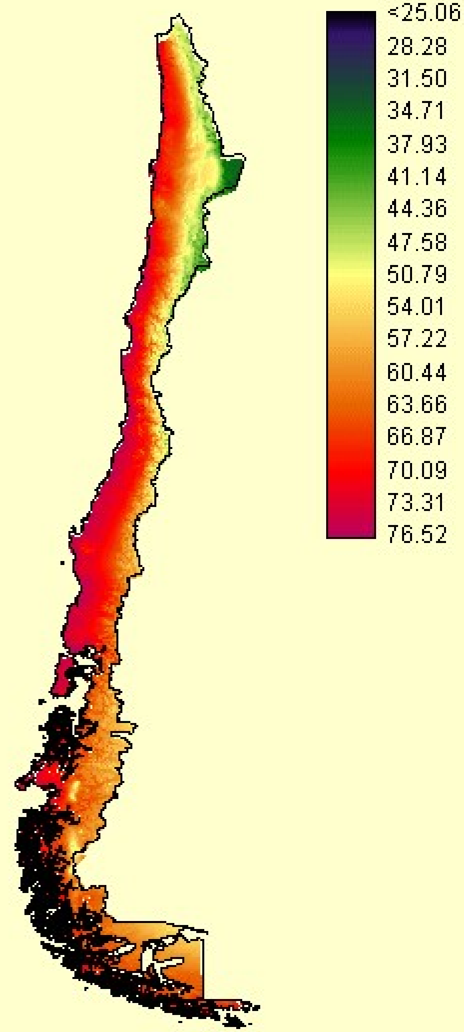


b(x,y)

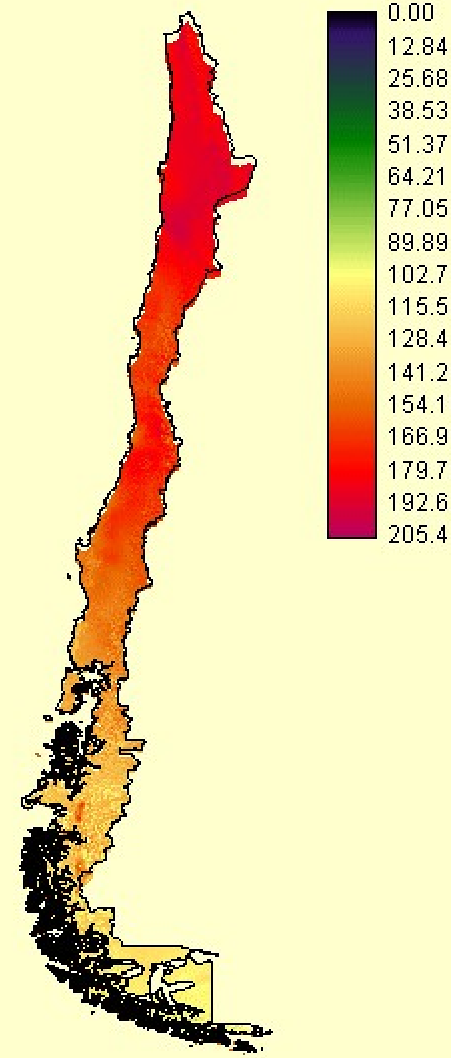




Radiación Global

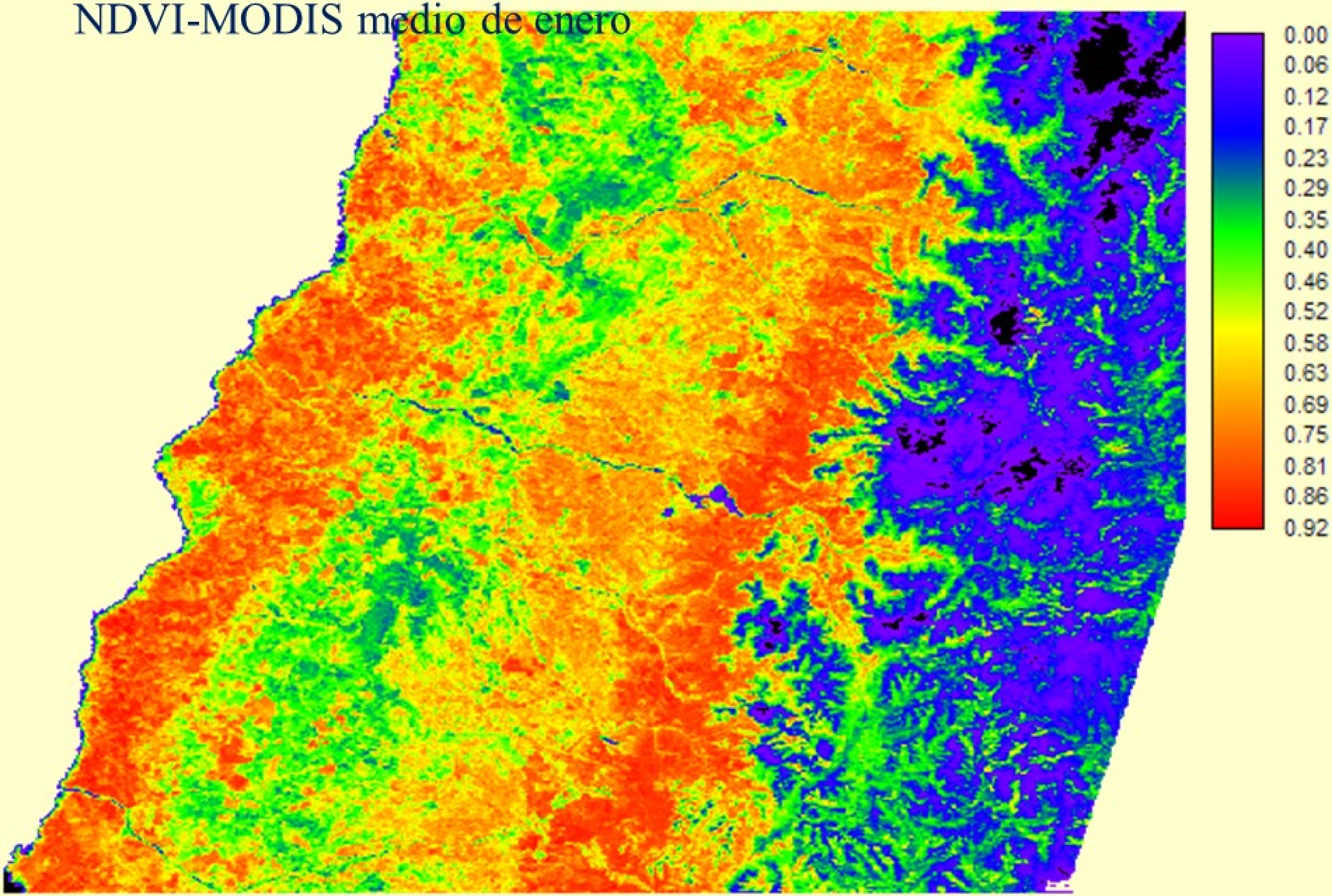


Humedad Relativa

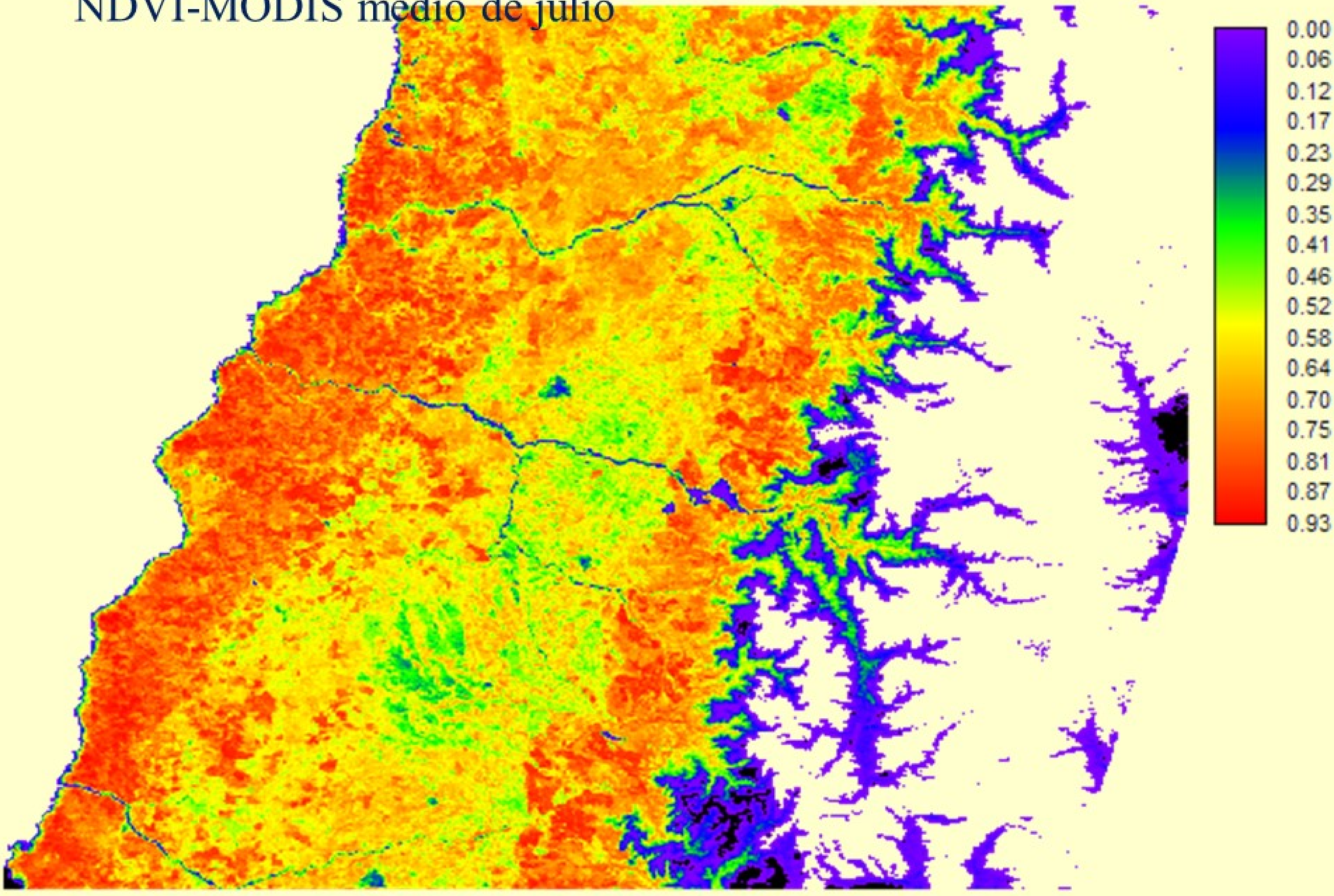


Evapotranspiración

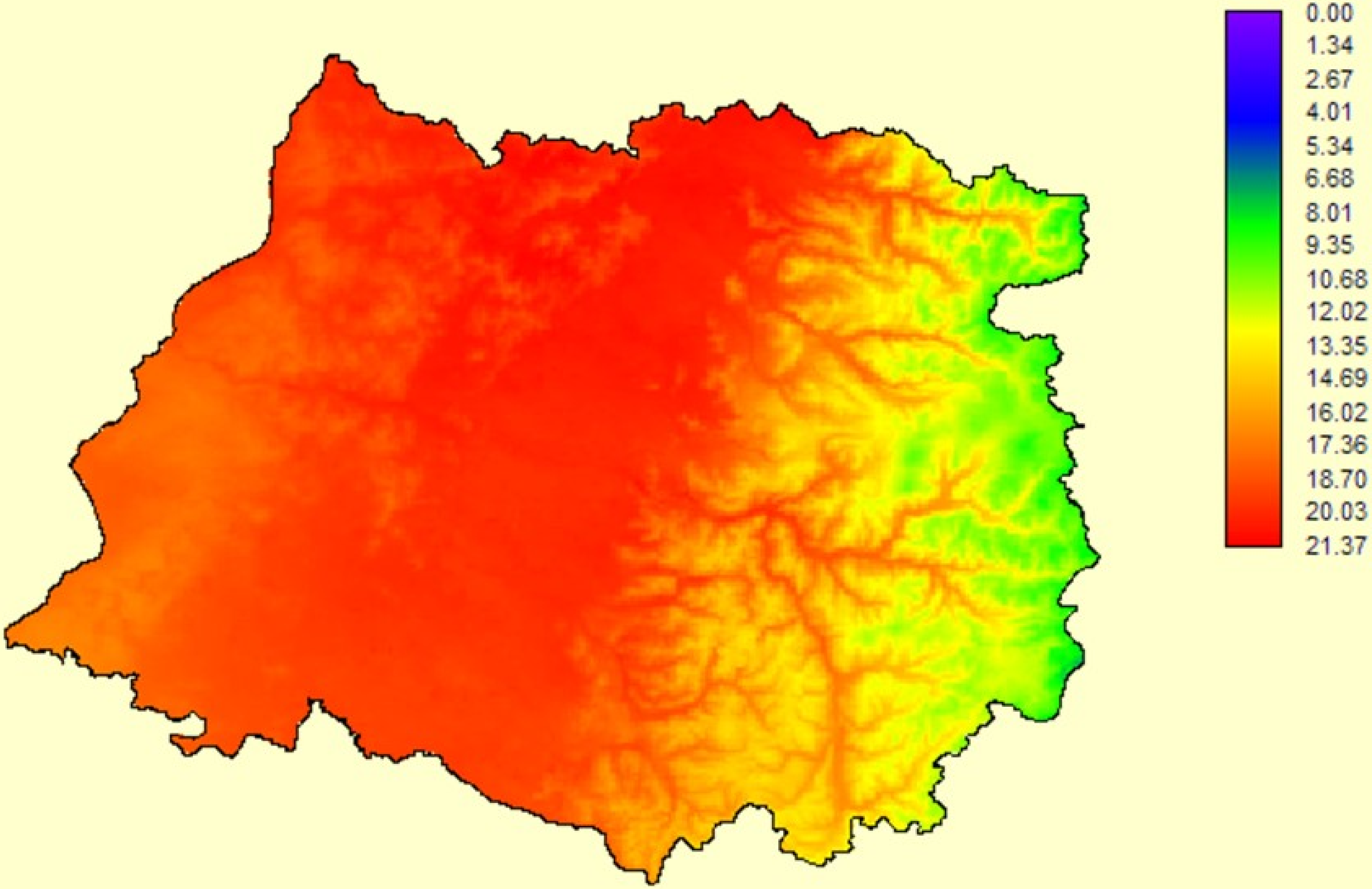
NDVI-MODIS medio de enero



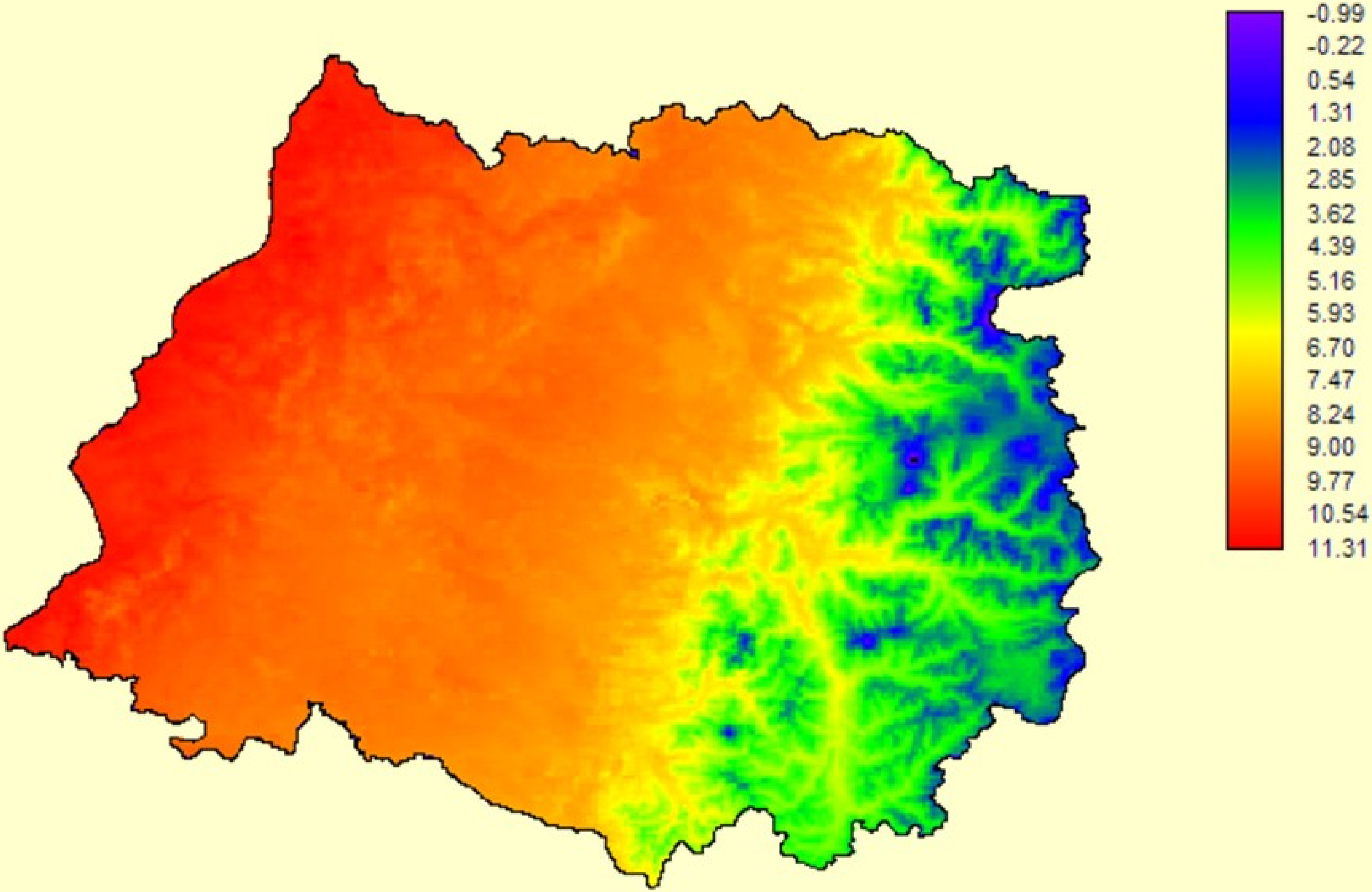
NDVI-MODIS medio de julio

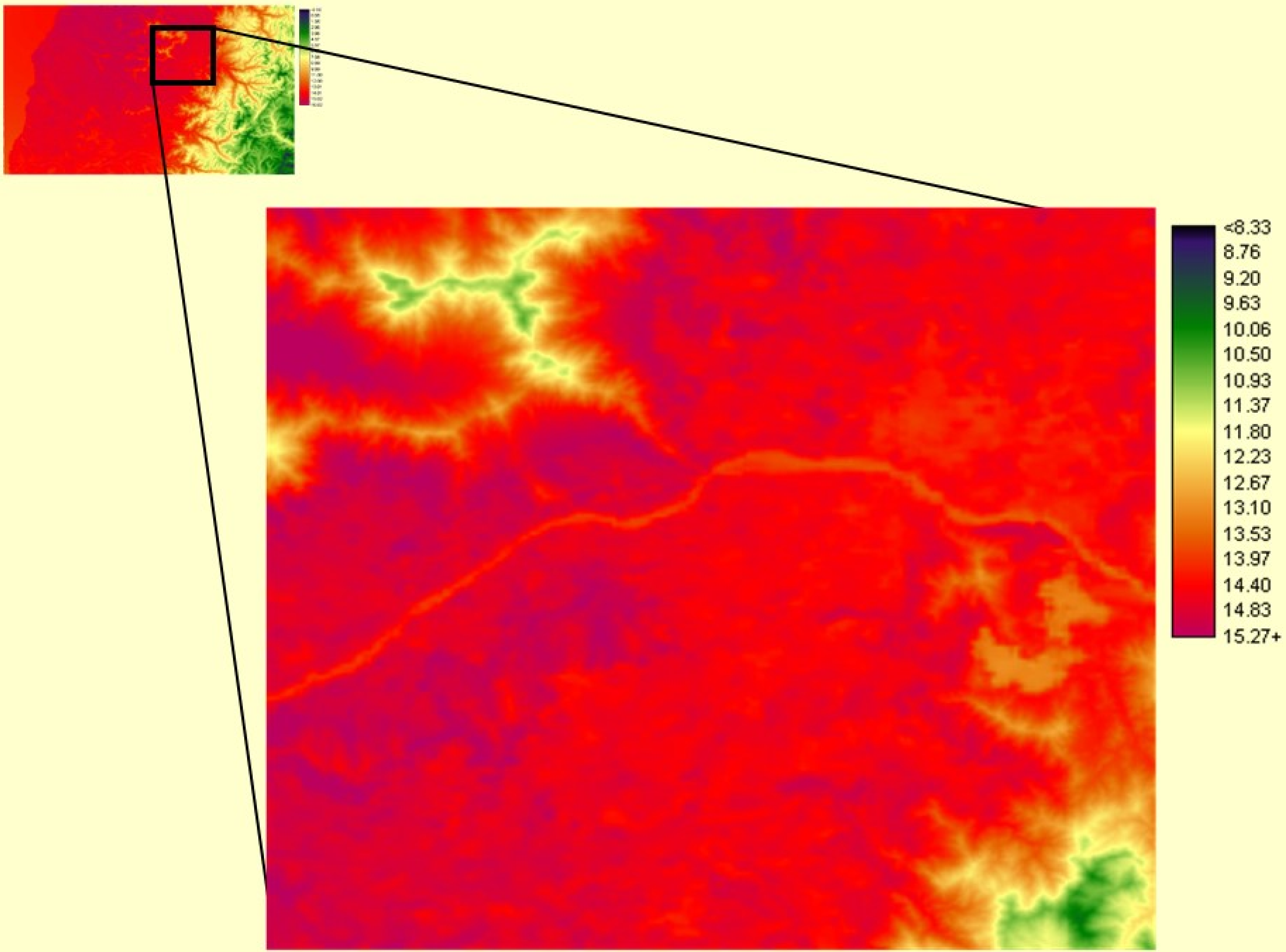


Temperatura media de enero

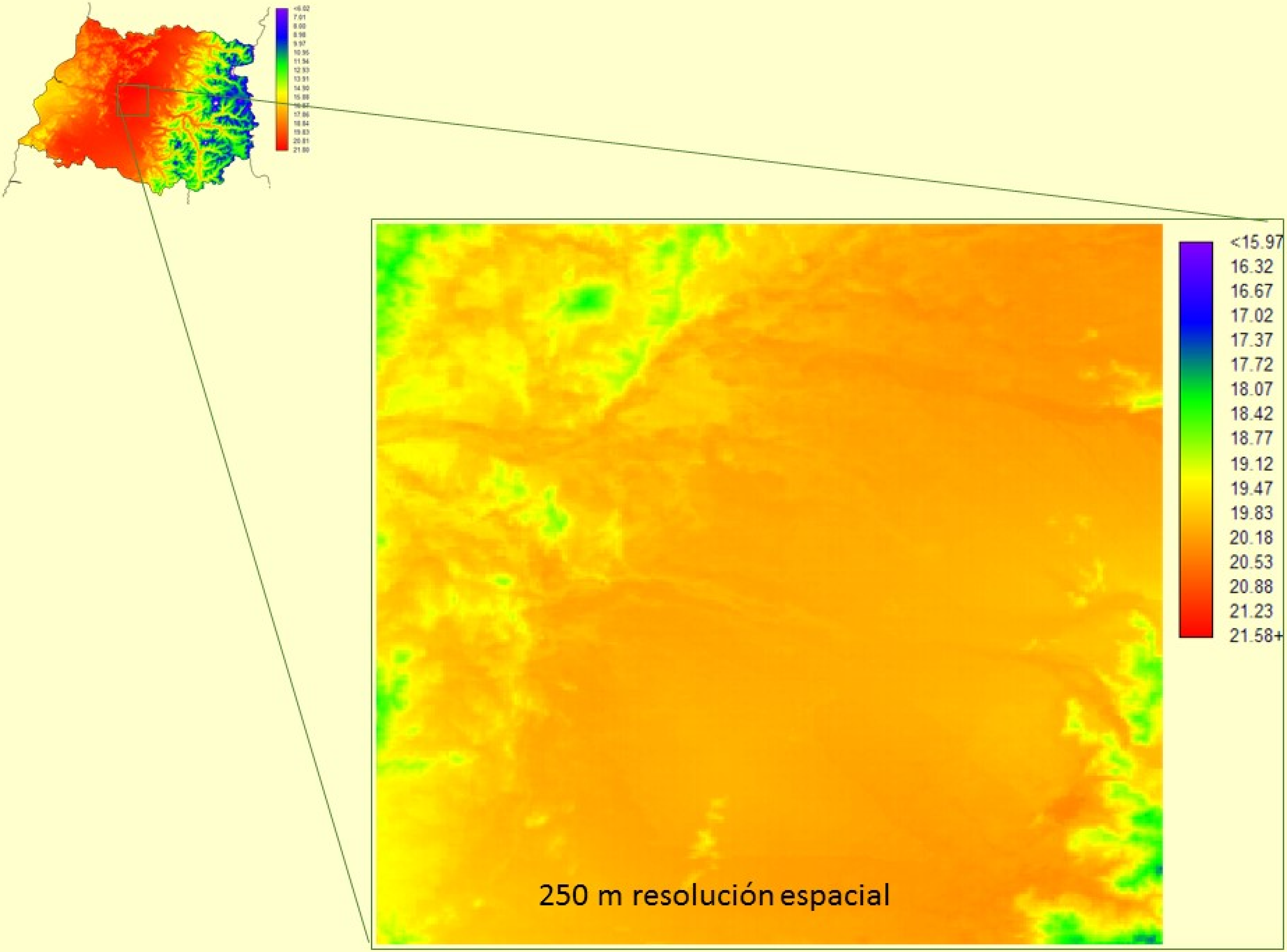


Temperatura media de julio



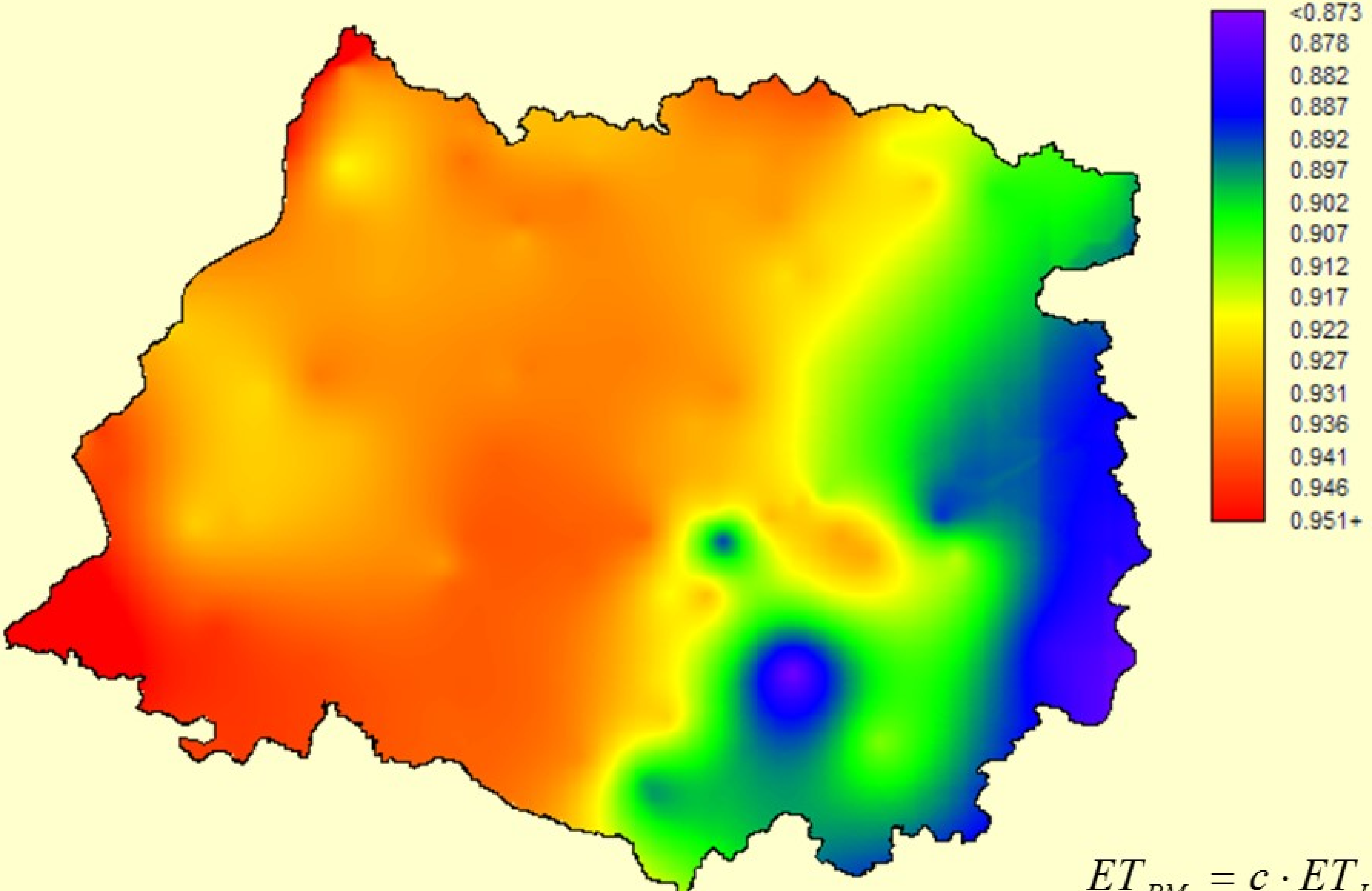


<8.33
8.76
9.20
9.63
10.06
10.50
10.93
11.37
11.80
12.23
12.67
13.10
13.53
13.97
14.40
14.83
15.27+



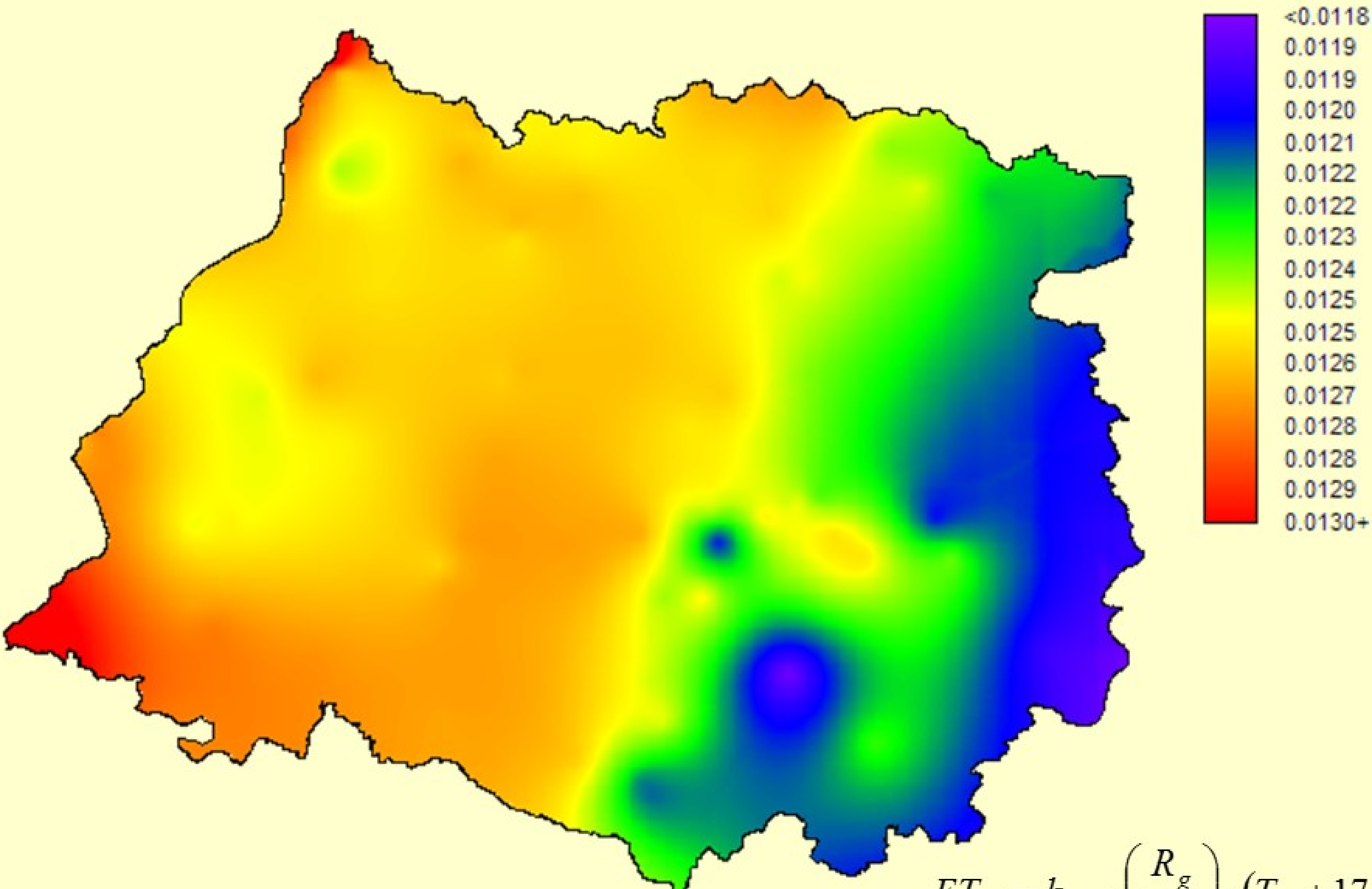
<15.97
16.32
16.67
17.02
17.37
17.72
18.07
18.42
18.77
19.12
19.47
19.83
20.18
20.53
20.88
21.23
21.58+
250 m resolución espacial

Variación espacial del coeficiente regresión

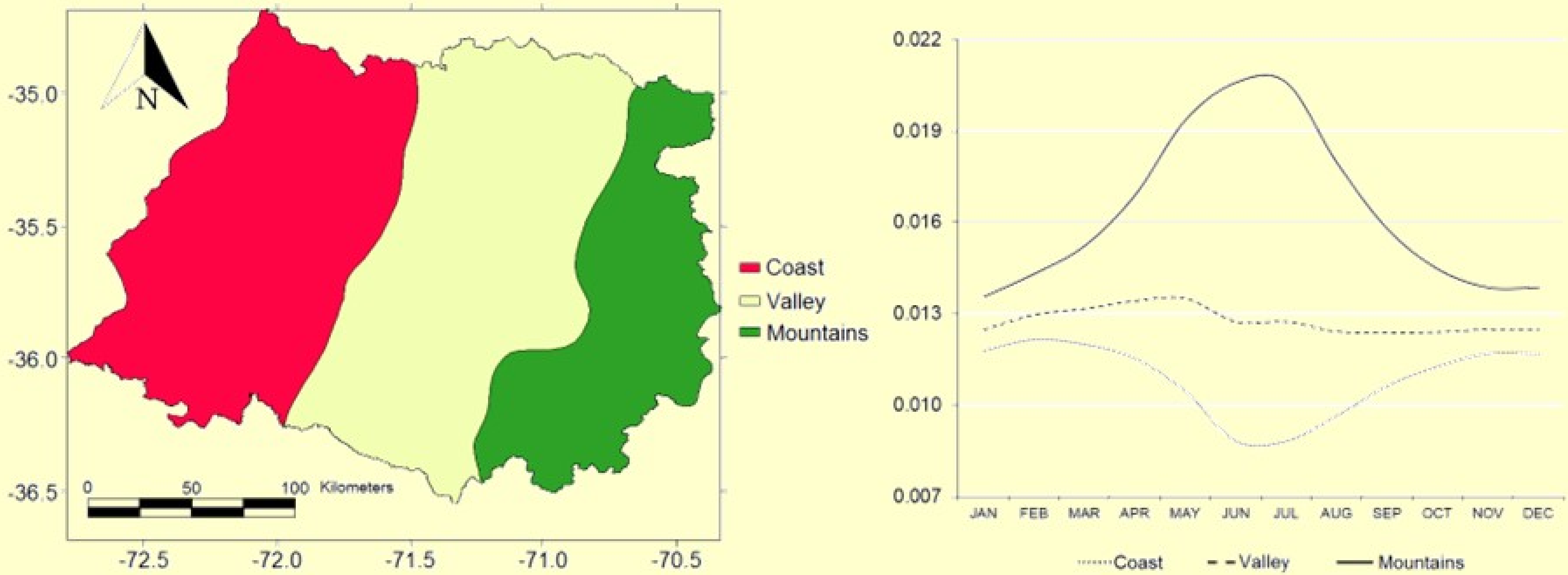


$$ET_{PM} = c \cdot ET_{HS}$$

Variación espacial del coeficiente k_{HS} de Hargreaves-Samani



$$ET_d = k_{HS} \cdot \left(\frac{R_g}{\lambda}\right) \cdot (T_m + 17.8)$$



(a) Geographical distribution of clusters

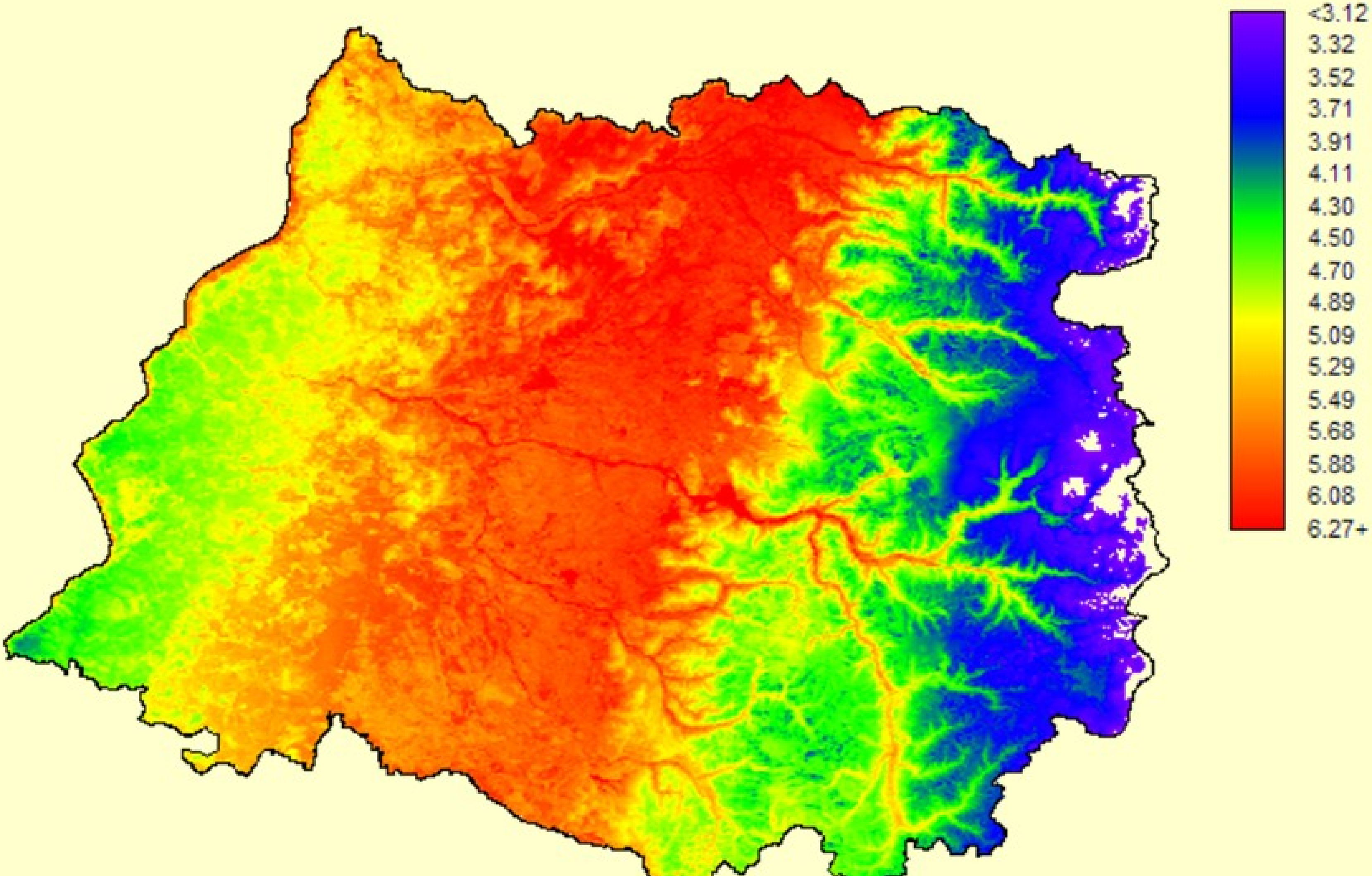
(b) Monthly variation of K_{HS} by cluster

Characterization of K_{HS} clusters in study area.

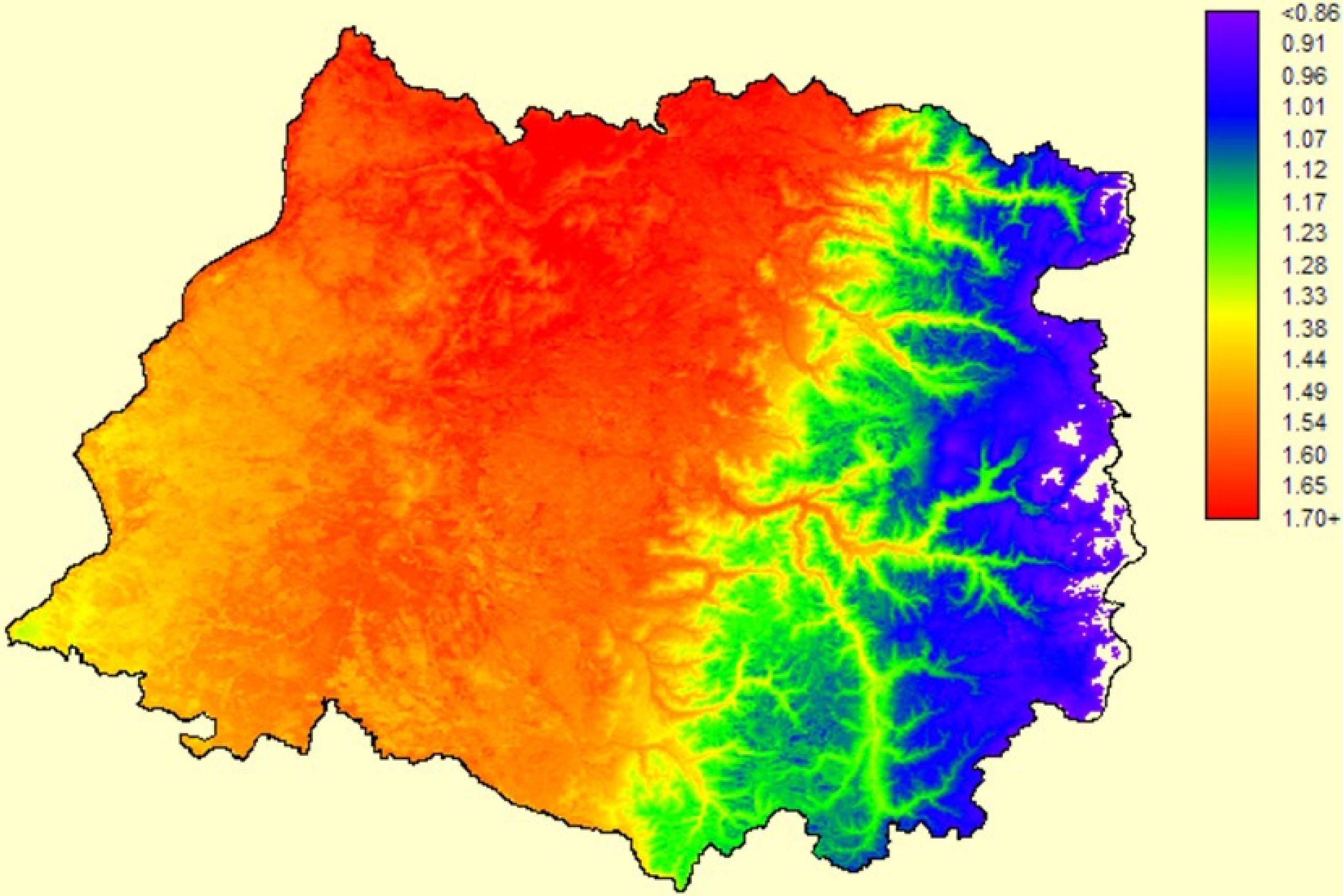
Monthly mean estimated values of K_{HS}.

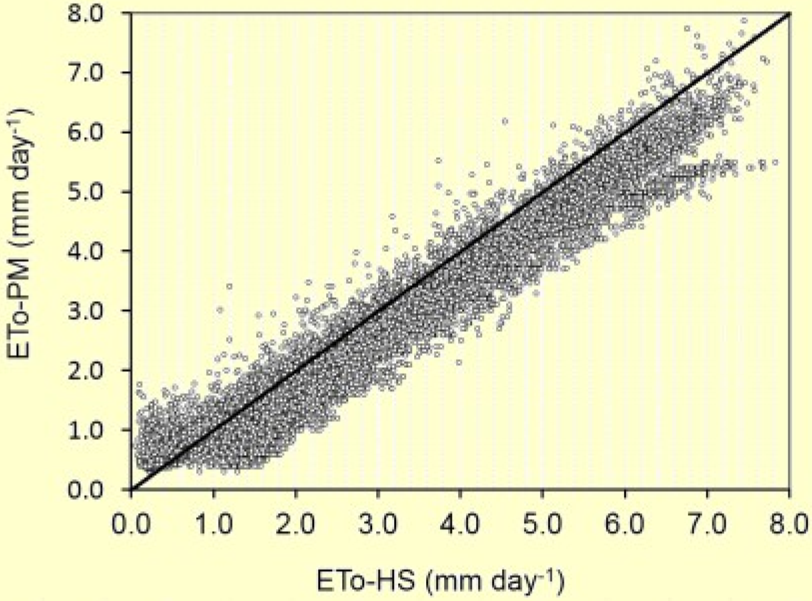
Cluster	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Coast	0.01177	0.01214	0.01198	0.01152	0.01044	0.00881	0.00881	0.00964	0.01062	0.01126	0.01168	0.01168	0.01086
Valley	0.01247	0.01296	0.01316	0.01342	0.01350	0.01273	0.01273	0.01241	0.01237	0.01239	0.01248	0.01248	0.01276
Mountains	0.01355	0.01431	0.01523	0.01690	0.01937	0.02060	0.02060	0.01797	0.01579	0.01447	0.01386	0.01386	0.01638

Evapotranspiración media de Enero (mm)

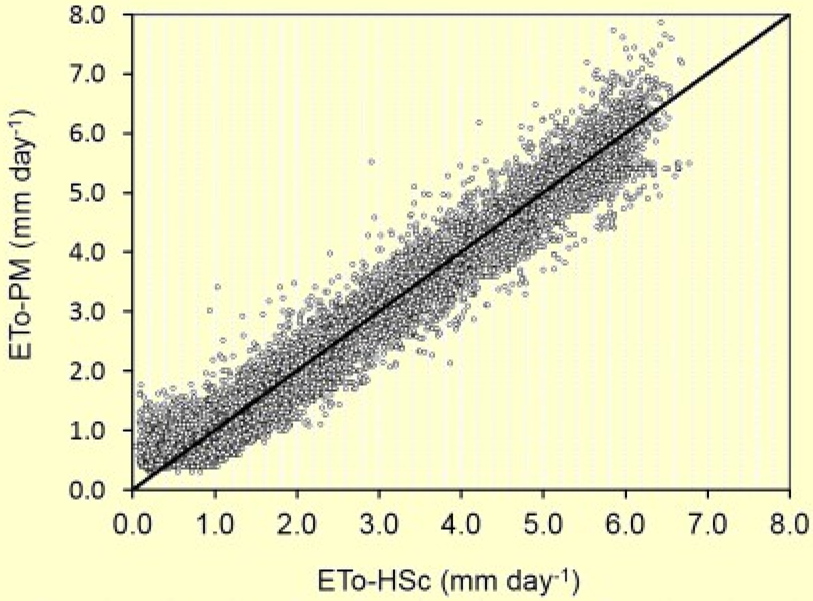


Evapotranspiración media de Julio (mm)





(a) Comparison of HS and PM



(b) Comparison of HSc and PM

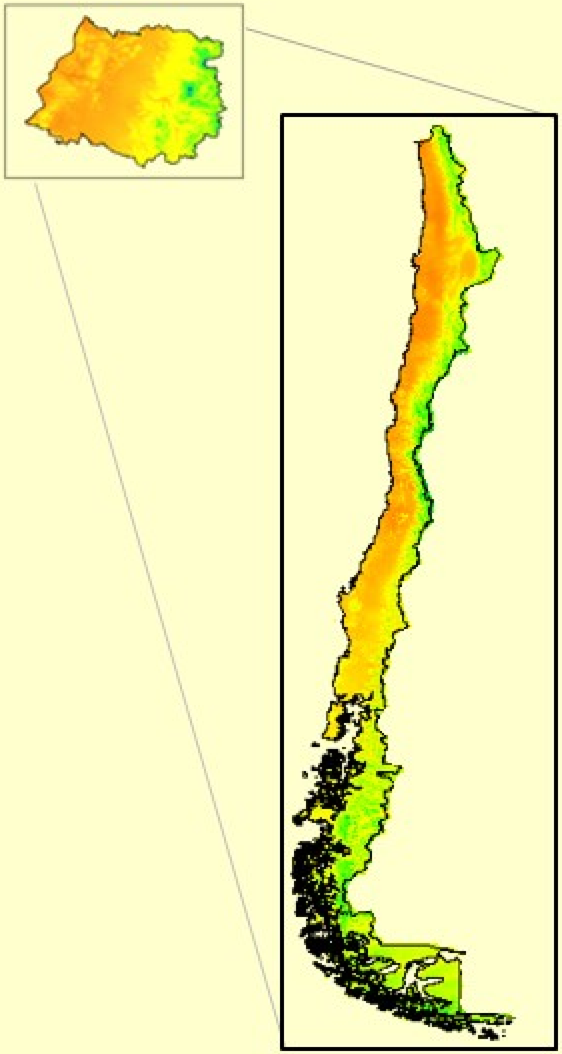
Performance of HS and HSc for validation.

III

COMO EVALUAR LOS IMPACTOS EN LA AGRICULTURA




Preguntas a responder

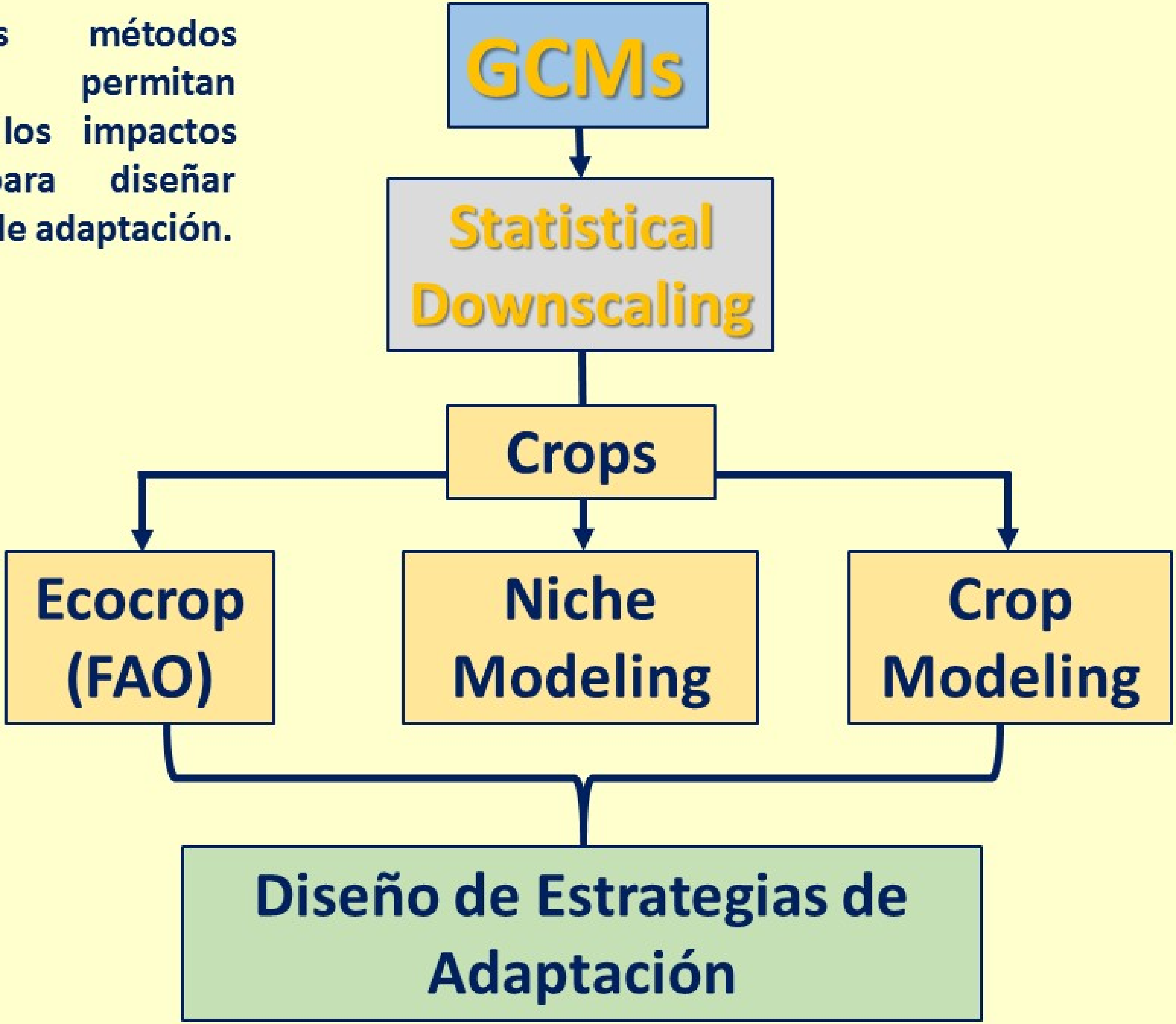


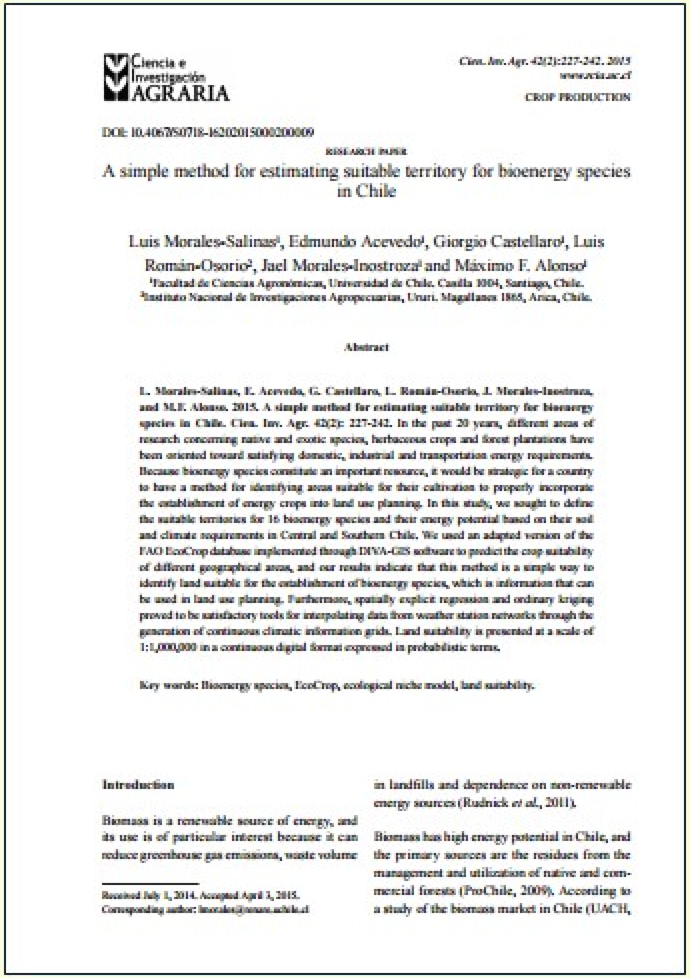
Donde puedo encontrar el clima actual de mi territorio en el futuro en el país?

Donde puedo encontrar el clima futuro de mi territorio en el país hoy?

Donde puedo encontrar el clima presente o futuro de mi territorio hoy en el país?

Necesitamos métodos que nos permitan cuantificar los impactos del cc para diseñar estrategias de adaptación.





Ciencia e Investigación AGRARIA

Cien. Inv. Agr. 42(2):227-242. 2015
www.rcia.uc.cl

CROP PRODUCTION

DOI: 10.4067/S0718-16202015000200009

RESEARCH PAPER

A simple method for estimating suitable territory for bioenergy species in Chile

Luis Morales-Salinas[1], Edmundo Acevedo[1], Giorgio Castellaro[1], Luis Román-Osorio[2], Jael Morales-Inostroza[1] and Máximo F. Alonso[1]

[1]Facultad de Ciencias Agronómicas, Universidad de Chile. Casilla 1004, Santiago, Chile.
[2]Instituto Nacional de Investigaciones Agropecuarias, Ururi. Magallanes 1865, Arica, Chile.

Abstract

L. Morales-Salinas, E. Acevedo, G. Castellaro, L. Román-Osorio, J. Morales-Inostroza, and M.F. Alonso. 2015. A simple method for estimating suitable territory for bioenergy species in Chile. Cien. Inv. Agr. 42(2): 227-242. In the past 20 years, different areas of research concerning native and exotic species, herbaceous crops and forest plantations have been oriented toward satisfying domestic, industrial and transportation energy requirements. Because bioenergy species constitute an important resource, it would be strategic for a country to have a method for identifying areas suitable for their cultivation to properly incorporate the establishment of energy crops into land use planning. In this study, we sought to define the suitable territories for 16 bioenergy species and their energy potential based on their soil and climate requirements in Central and Southern Chile. We used an adapted version of the FAO EcoCrop database implemented through DIVA-GIS software to predict the crop suitability of different geographical areas, and our results indicate that this method is a simple way to identify land suitable for the establishment of bioenergy species, which is information that can be used in land use planning. Furthermore, spatially explicit regression and ordinary kriging proved to be satisfactory tools for interpolating data from weather station networks through the generation of continuous climatic information grids. Land suitability is presented at a scale of 1:1,000,000 in a continuous digital format expressed in probabilistic terms.

Key words: Bioenergy species, EcoCrop, ecological niche model, land suitability.

Introduction

Biomass is a renewable source of energy, and its use is of particular interest because it can reduce greenhouse gas emissions, waste volume in landfills and dependence on non-renewable energy sources (Rudnick *et al.*, 2011).

Biomass has high energy potential in Chile, and the primary sources are the residues from the management and utilization of native and commercial forests (ProChile, 2009). According to a study of the biomass market in Chile (UACH,

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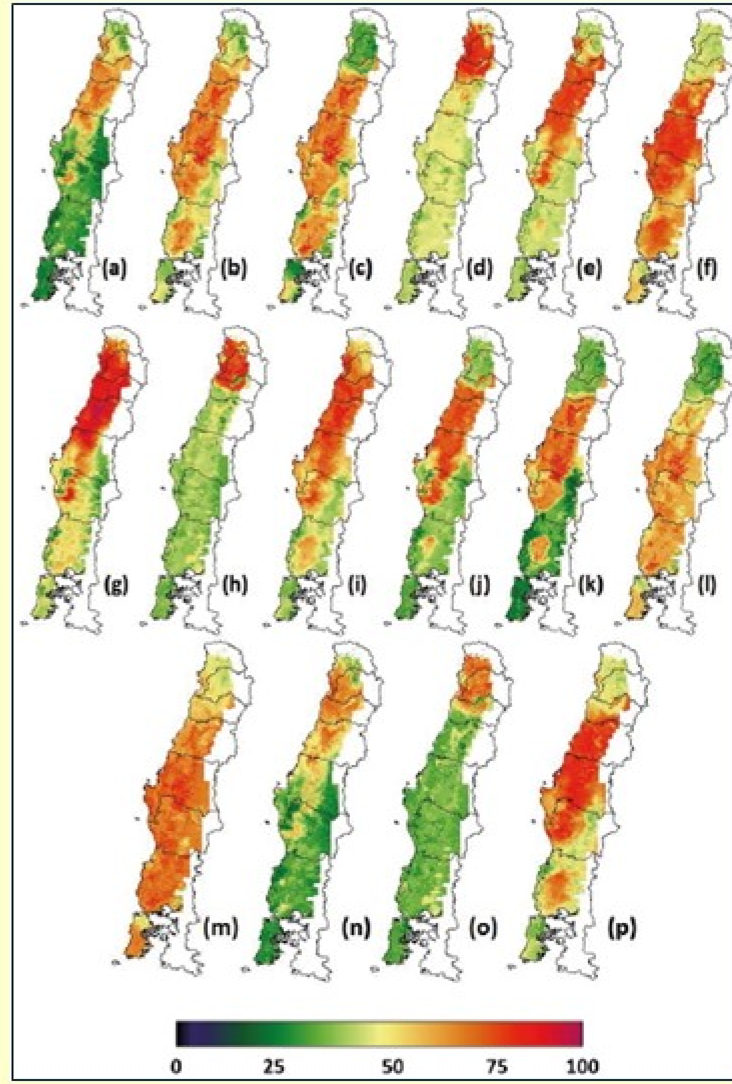
Corresponding author: lmorales@renare.uchile.cl

MORALES-SALINAS, Luis et al. **A simple method for estimating suitable territory for bioenergy species in Chile.** *Cienc. Inv. Agr.* [online]. 2015, vol.42, n.2, pp. 227-242. ISSN 0718-1620.



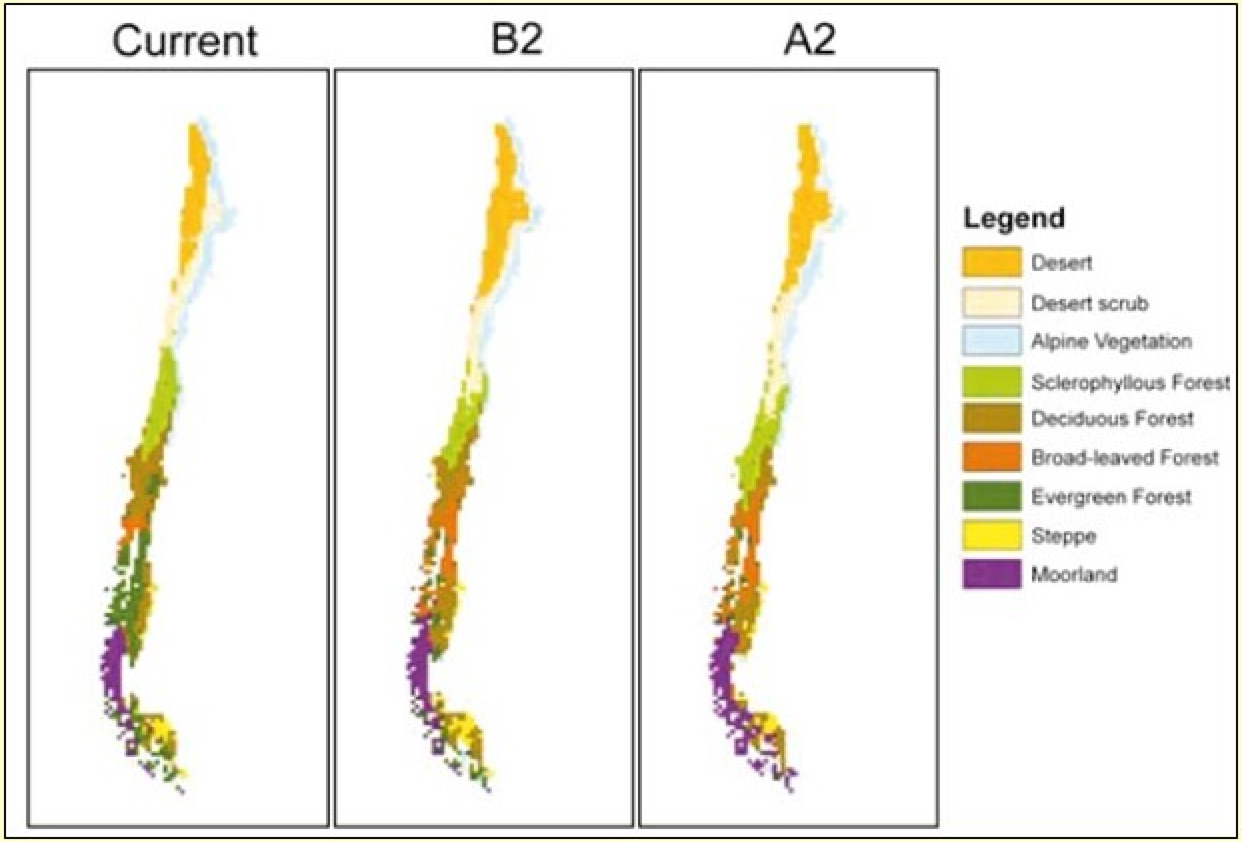
Land suitability maps for *Acacia dealbata* (a), *A. mearnsii* (b), *A. melanoxylon* (c), *A. saligna* (d), *Arundo donax* (e), *Miscanthus x giganteus* (f), *Paulownia spp.* (g), *Salix viminalis* (h), *Eucalyptus camaldulensis* (i), E. *globulus* (j), *E. nitens* (k), *Populus deltoides* (l), *Populus* spp. (m), *Robinia pseudoacacia* (n), *Opuntia ficus-indica* (o) and *Panicum virgatum* (p).

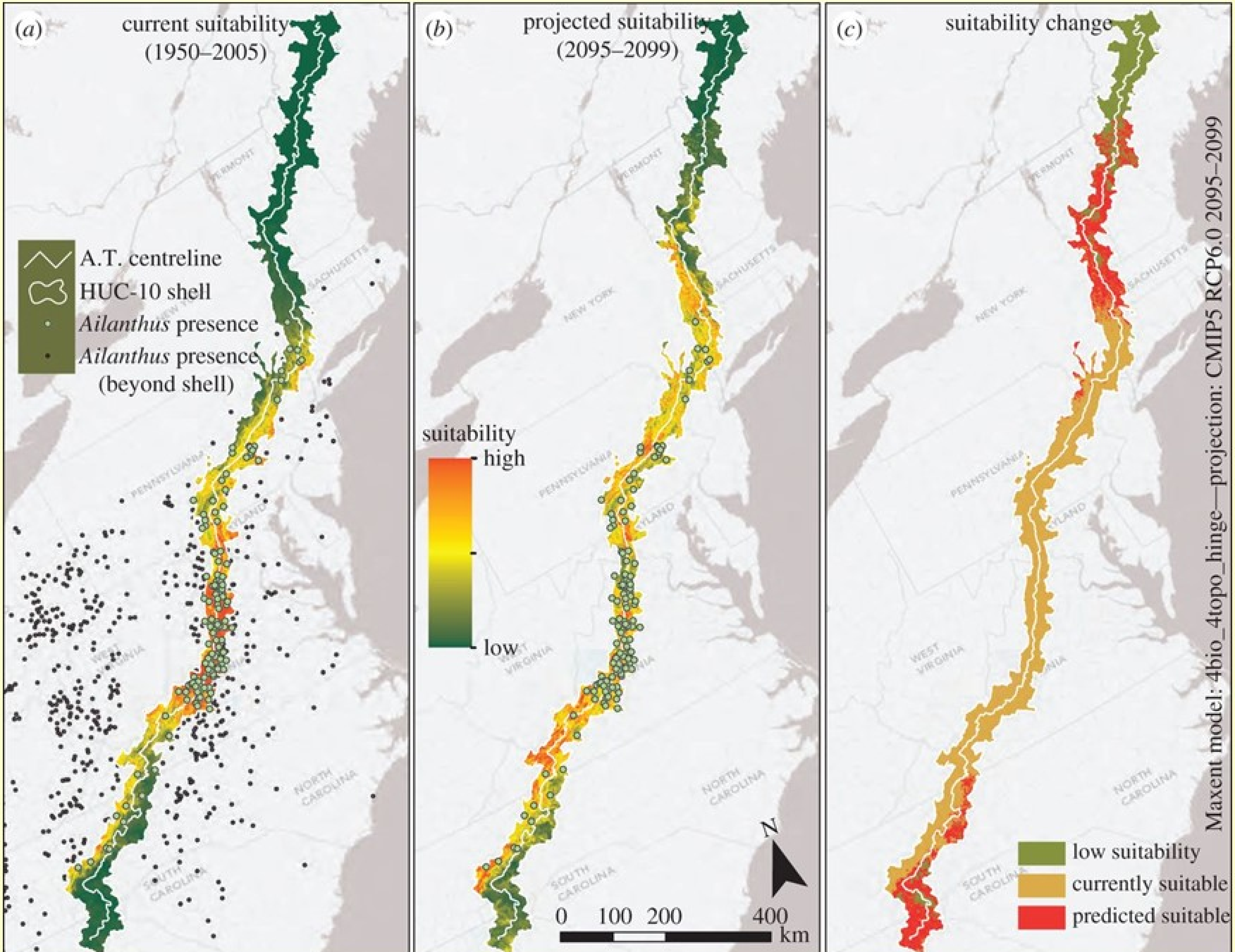
CHANGES IN THE MAIN VEGETATION TYPES OF CHILE PREDICTED UNDER CLIMATE CHANGE BASED ON A PRELIMINARY STUDY: MODELS, UNCERTAINTIES AND ADAPTING RESEARCH TO A DYNAMIC BIODIVERSITY WORLD

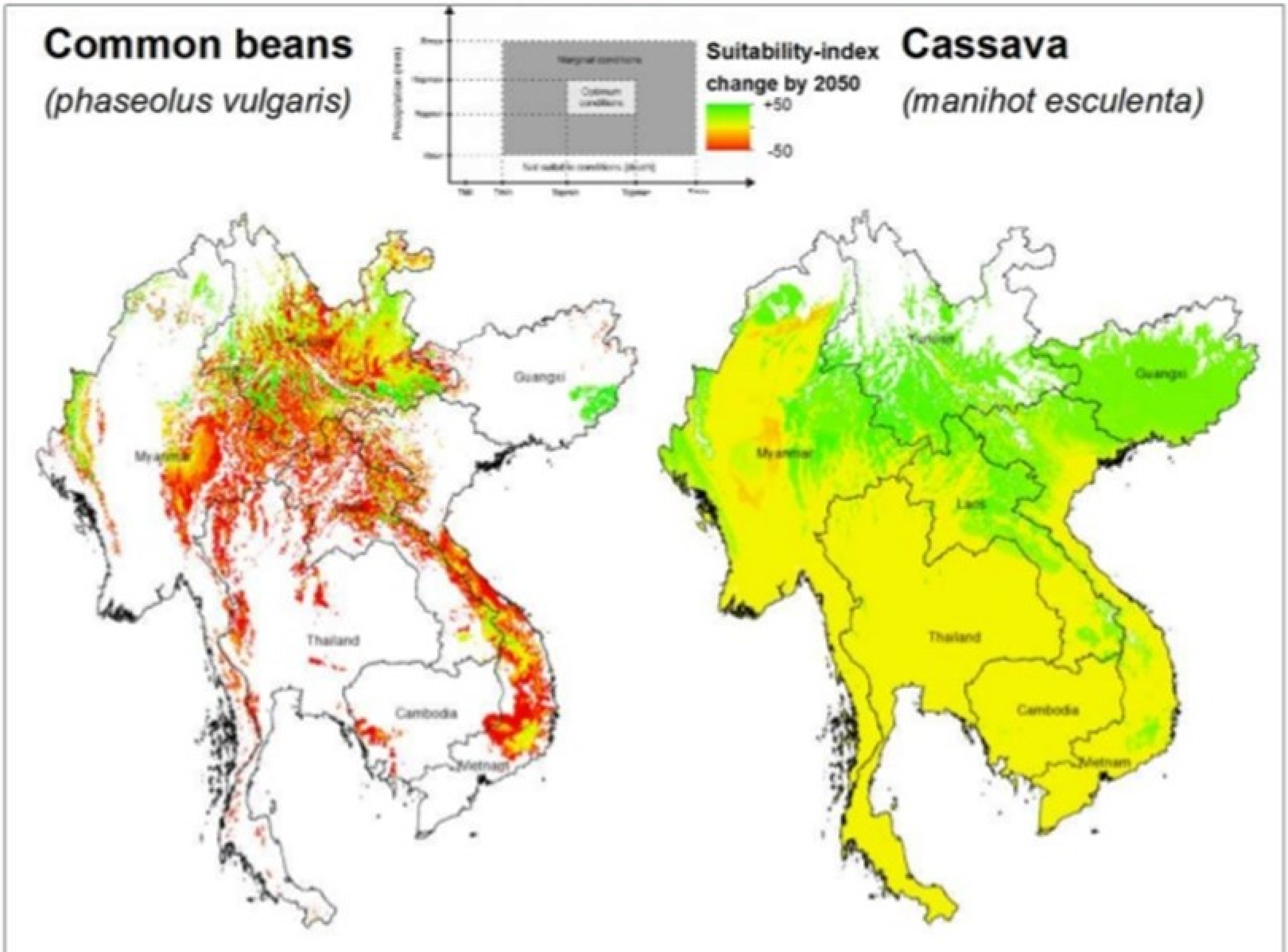
PREDICCIONES DE CAMBIOS EN LOS PRINCIPALES TIPOS DE VEGETACIÓN DE CHILE BAJO CAMBIO CLIMÁTICO BASADOS EN UN ESTUDIO PRELIMINAR: MODELOS, INCERTIDUMBRES Y ADAPTACIÓN DE LA INVESTIGACIÓN PARA UN MUNDO DE BIODIVERSIDAD DINÁMICA

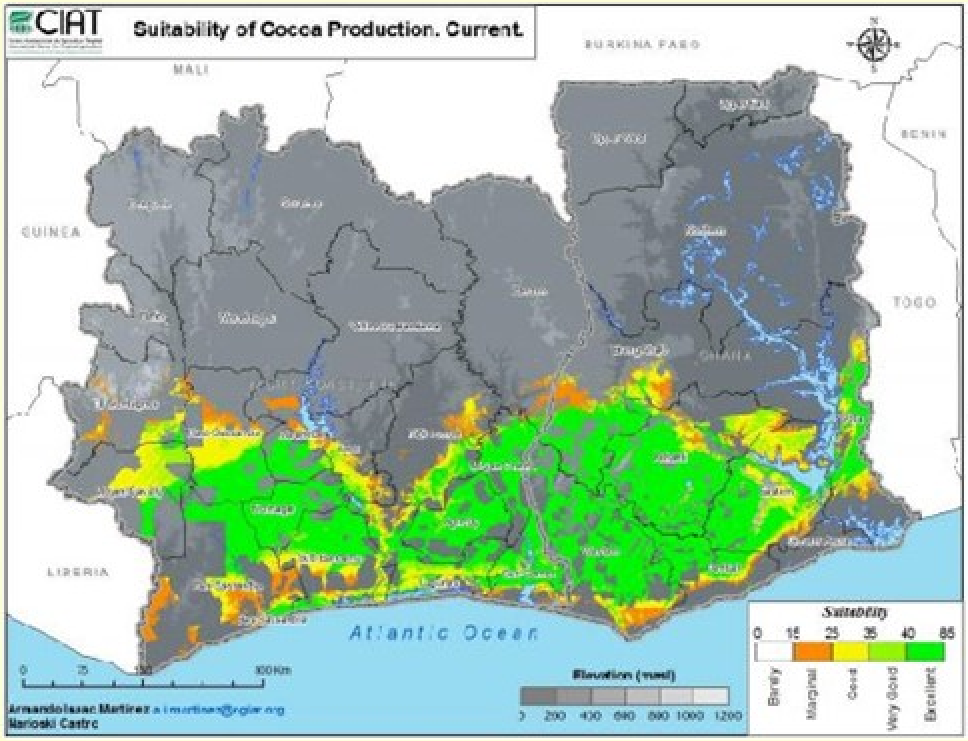
RESUMEN

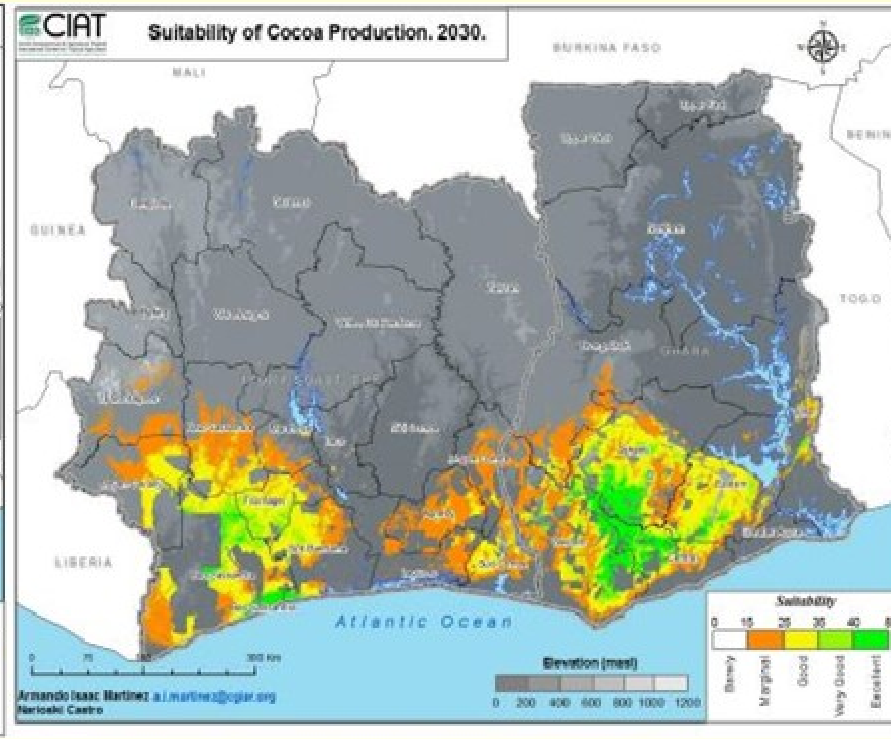
PLISCOFF, Patricio; ARROYO, Mary T. K and CAVIERES, Lohengrin. **Predicciones de cambios en los principales tipos de vegetación de Chile bajo cambio climático basados en un estudio preliminar: Modelos, incertidumbres y adaptación de la investigación para un mundo de biodiversidad dinámica.** *Anales Instituto Patagonia (Chile)* [online]. 2012, vol.40, n.1, pp. 81-86. ISSN 0718-686X.

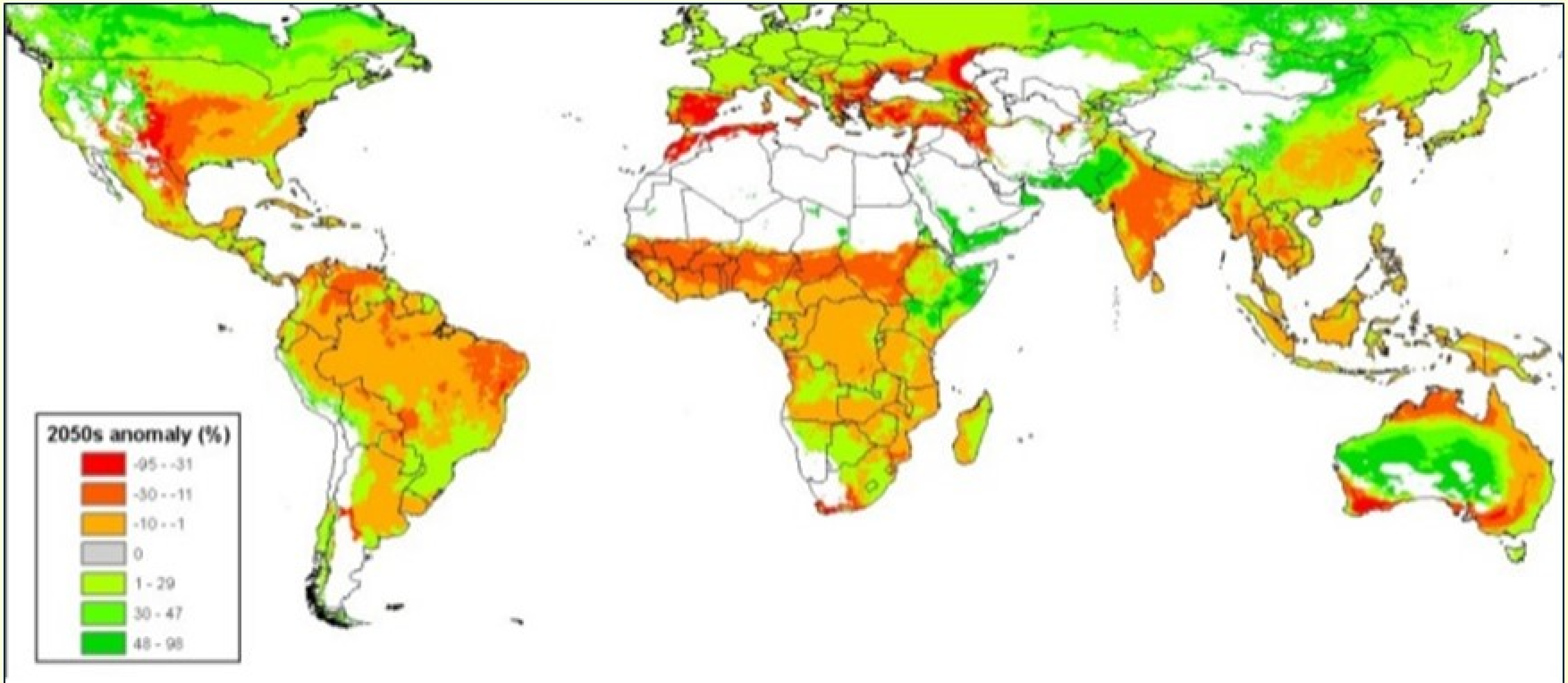



(a)
current suitability
(1950–2005)
A.T. centreline
HUC-10 shell
Ailanthus presence
Ailanthus presence
(beyond shell)
(b)
projected suitability
(2095–2099)
suitability
high
low
0 100 200 400
km
N
(c)
suitability change
low suitability
currently suitable
predicted suitable
Maxent model: 4bio_4topo_hinge—projection: CMIP5 RCP6.0 2095–2099
VERMONT
NEW YORK
PENNSYLVANIA
WEST VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA


Common beans
(phaseolus vulgaris)
Suitability-index
change by 2050
+50
-50
Cassava
(manihot esculenta)
Guangxi
Myanmar
Thailand
Cambodia
Vietnam
Yunnan
Laos

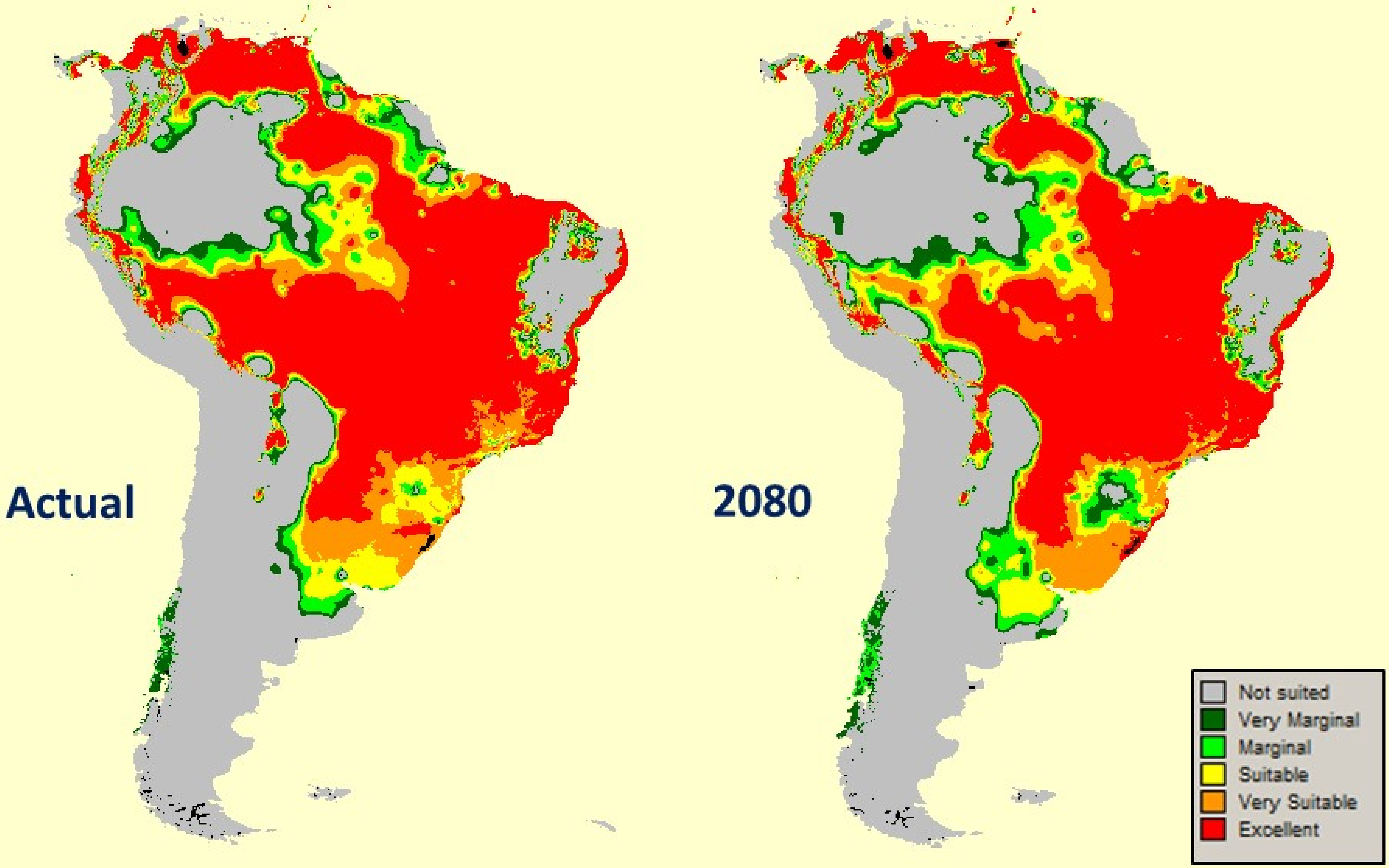

CIAT
Suitability of Cocoa Production. Current.
BURKINA FASO
MALI
GUINEA
GHANA
TOGO
LIBERIA
Atlantic Ocean
Suitability
0 15 25 35 40 85
Barely
Marginal
Good
Very Good
Excellent
Elevation (masl)
0 200 400 600 800 1000 1200
0 75 150 300 Km
Armando Isaac Martinez a.i.martinez@cgiar.org
Narioski Castro


CIAT
Suitability of Cocoa Production. 2030.
BURKINA FASO
MALI
BENIN
GUINEA
GHANA
TOGO
LIBERIA
Atlantic Ocean
Suitability
0 15 25 35 40 85
Barely
Marginal
Good
Very Good
Excellent
Elevation (masl)
0 200 400 600 800 1000 1200
0 75 150 300 Km
Armando Isaac Martinez a.i.martinez@cgiar.org
Narioski Castro

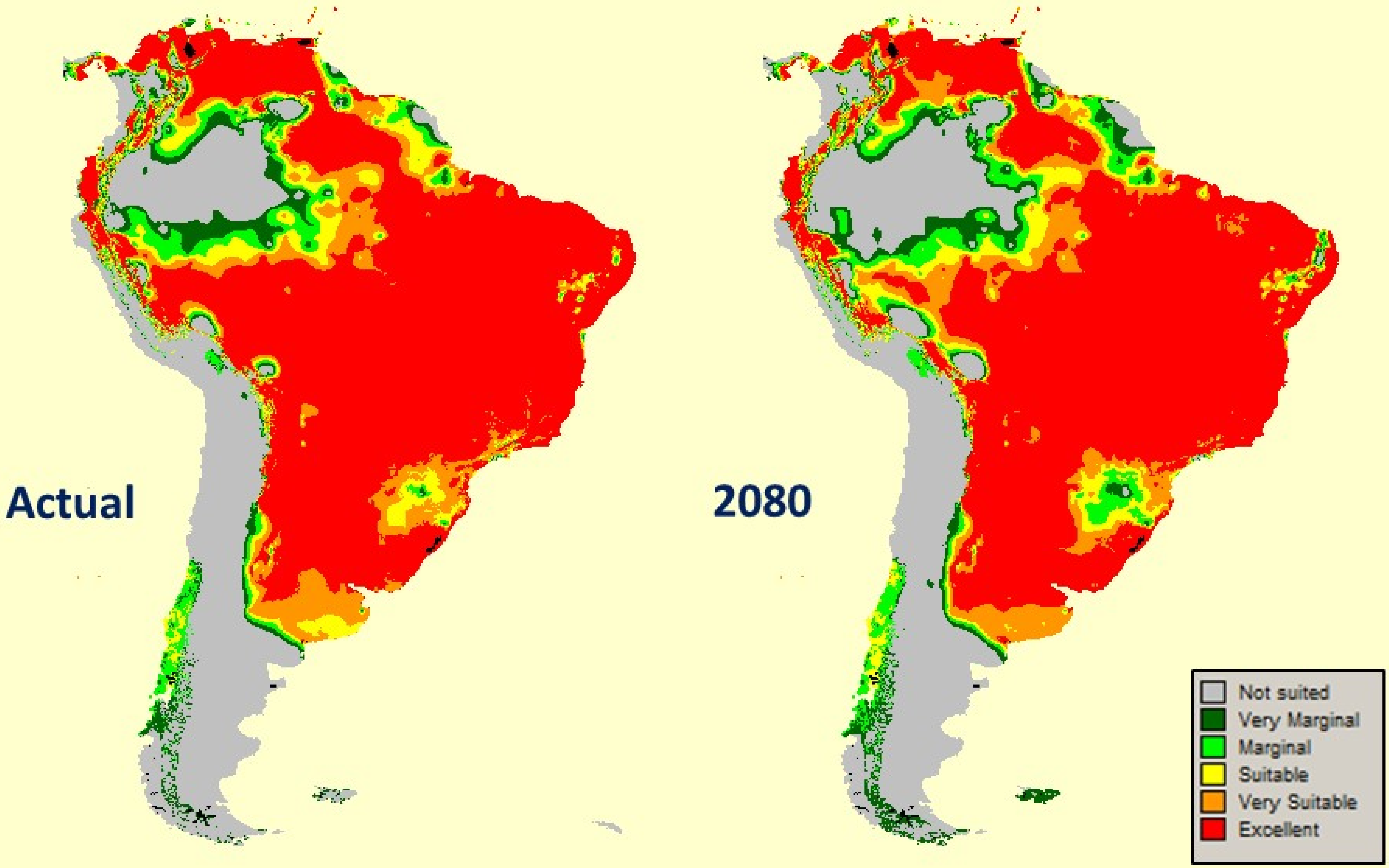


Average projected % change in suitability for 50 crops, to 2050

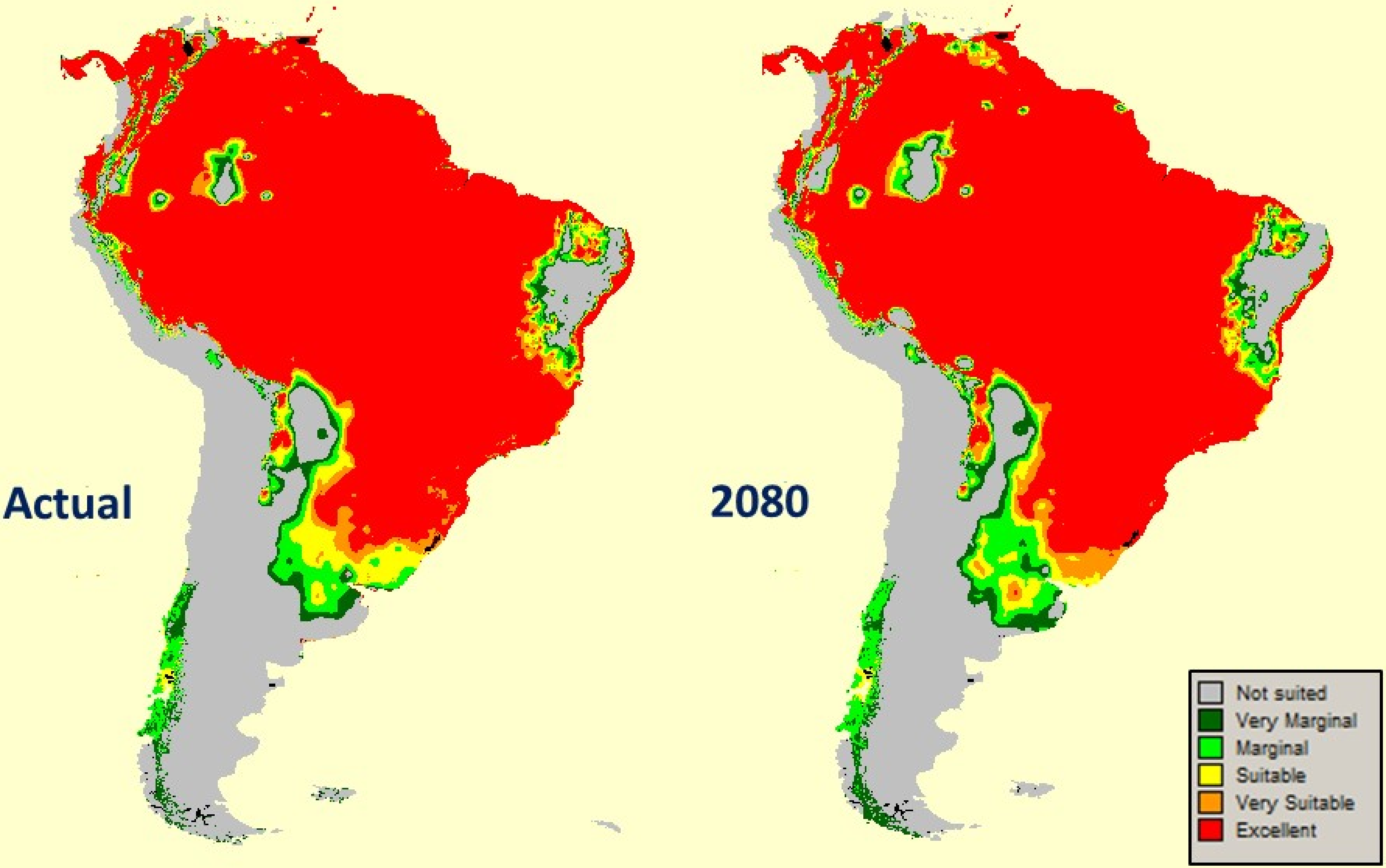
Melocotón


Actual
2080
Not suited
Very Marginal
Marginal
Suitable
Very Suitable
Excellent

Cereza


Actual
2080
Not suited
Very Marginal
Marginal
Suitable
Very Suitable
Excellent

Ciruela



Actual
2080
Not suited
Very Marginal
Marginal
Suitable
Very Suitable
Excellent

Cydia pomonella

Journal of Economic Entomology Advance Access published June 26, 2015

Ecology and Behavior

Assessing the Global Risk of Establishment of *Cydia pomonella* (Lepidoptera: Tortricidae) using CLIMEX and MaxEnt Niche Models

Sunil Kumar,[1,2] Lisa G. Neven,[3] Hongyu Zhu,[4] and Runzhi Zhang[4]

J. Econ. Entomol. 1–12 (2015); DOI: 10.1093/jee/tov166

ABSTRACT Accurate assessment of insect pest establishment risk is needed by national plant protection organizations to negotiate international trade of horticultural commodities that can potentially carry the pests and result in inadvertent introductions in the importing countries. We used mechanistic and correlative niche models to quantify and map the global patterns of the potential for establishment of codling moth (*Cydia pomonella* L.), a major pest of apples, peaches, pears, and other pome and stone fruits, and a quarantine pest in countries where it currently does not occur. The mechanistic model CLIMEX was calibrated using species-specific physiological tolerance thresholds, whereas the correlative model MaxEnt used species occurrences and climatic spatial data. Projected potential distribution from both models conformed well to the current known distribution of codling moth. None of the models predicted suitable environmental conditions in countries located between 20°N and 20°S potentially because of shorter photoperiod, and lack of chilling requirement (<60 d at ≤10°C) in these areas for codling moth to break diapause. Models predicted suitable conditions in South Korea and Japan where codling moth currently does not occur but where its preferred host species (i.e., apple) is present. Average annual temperature and latitude were the main environmental variables associated with codling moth distribution at global level. The predictive models developed in this study present the global risk of establishment of codling moth, and can be used for monitoring potential introductions of codling moth in different countries and by policy makers and trade negotiators in making science-based decisions.

KEY WORDS biosecurity, species distribution modeling, pest risk analysis, insect pest, quarantine pest

The codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae), is one of the most destructive and economically important fruit pests of apples, its preferred host, as well as walnuts, pears, apricots, and plums in most fruit-growing temperate regions of the world (Barnes 1991, Beers et al. 1993, Neven 2012). It is a pest of quarantine concern in several countries and regions where it currently does not occur (e.g., Colombia, Japan, South Korea, and Chinese Taiwan). Codling moth has the potential to cause 100% infestation in untreated apple orchards (Beers et al. 2003). Other tree fruits such as pears (*Pyrus* spp.) and walnuts are less susceptible to codling moth infestation (Barnes 1991). Codling moth is considered to have originated somewhere in eastern Eurasia and was inadvertently introduced across the world through infested fruits (Lloyd 1960); it was introduced to North America around 1750 (Slingerland 1898).

Codling moth is an internal feeding pest and its biology is very well-studied because of its high economic importance (Neven et al. 2000, Neven 2012). It is a multivoltine species with a facultative diapause, and has the ability to adapt to diverse climatic conditions. This pest has one to five generations per year with fewer generations further away from the equator (Anonymous 2014a). *C. pomonella* has five larval instars and overwinters under the tree bark or at the base of the tree as fifth-instar diapausing larvae (Weitzner and Whalon 1987). Diapause is triggered primarily by shorter day lengths in late summer (Riedl 1983; Neven 2012, 2013). The critical photoperiod (i.e., the day length at which ≥50% of the population enters diapause) for codling moth varies from 13.5 to 15.5 h of day light (Shel'deshova 1967, Anonymous 2014b). *C. pomonella* also has chilling requirement of <60 d at ≤10°C temperature to break diapause (Neven 2013).

International trade of fruits, packing materials, and other commodities (e.g., seeds and plant parts) can potentially carry pests and cause inadvertent introductions in importing countries where the pest is not established. Therefore, the World Trade Organization (WTO) requires its members to establish national Sanitary and Phytosanitary Measures (SPS; WTO 2014) measures consistent with international standards (WTO 2014). The plants, insects, and disease pathogens

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[2] Corresponding author, e-mail: Sunil.Kumar@colostate.edu.
[3] United States Department of Agriculture Agricultural Research Service, Yakima Agricultural Research Laboratory, 5230 Konnowac Pass Rd., Wapato, WA 98951.
[4] Institute of Zoology, Chinese Academy of Sciences, Beichen West Rd., Chaoyang, Beijing 100101, China.

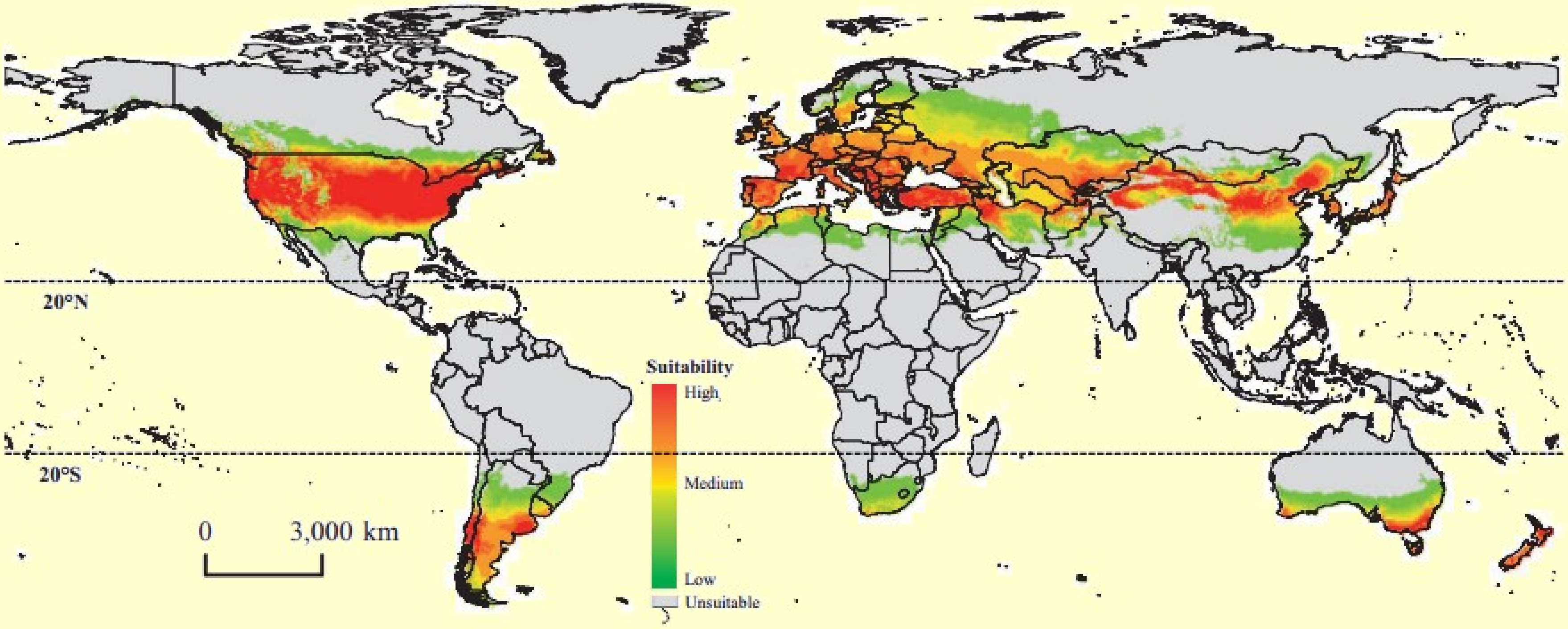


Fig. 1. Global risk of establishment of codling moth using MaxEnt model.

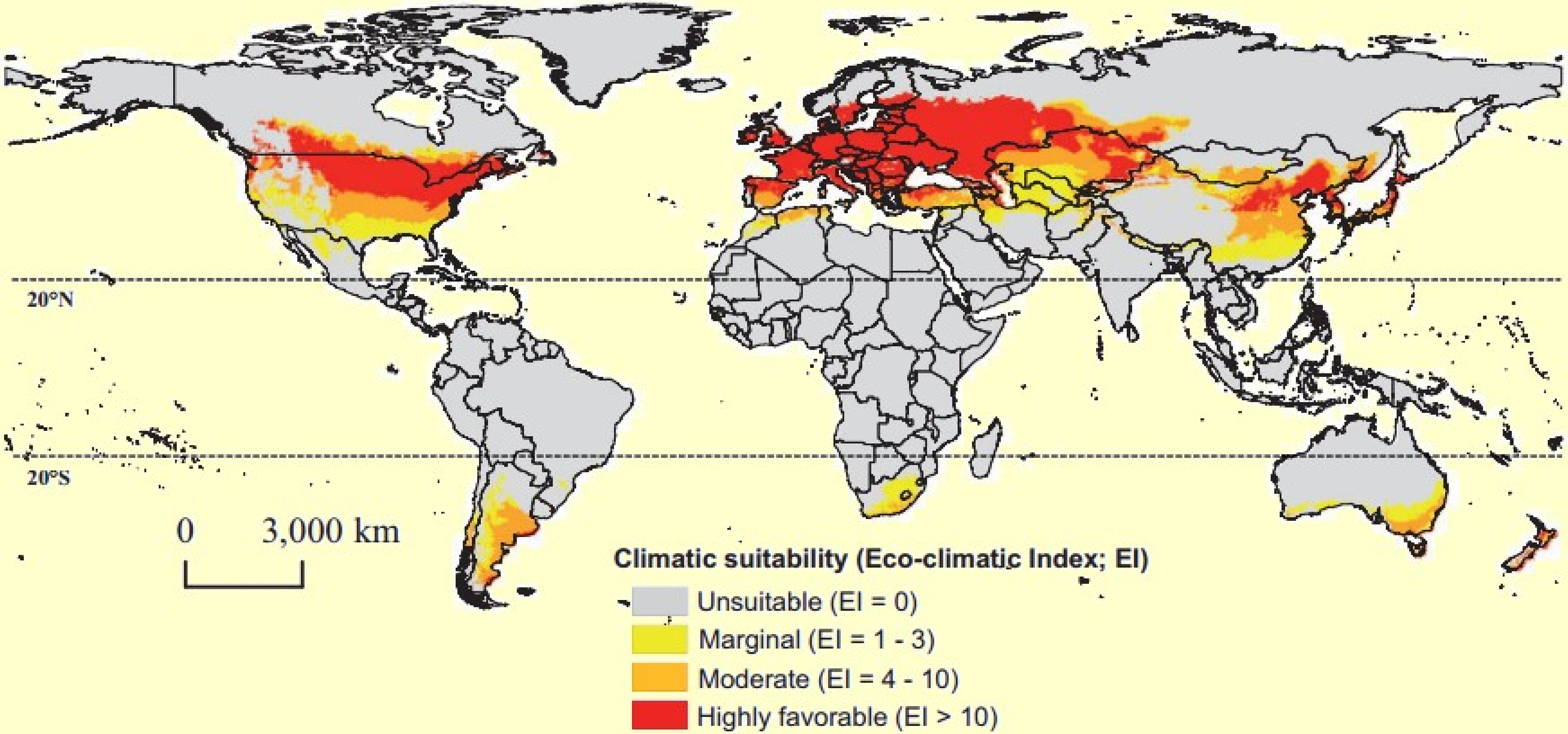
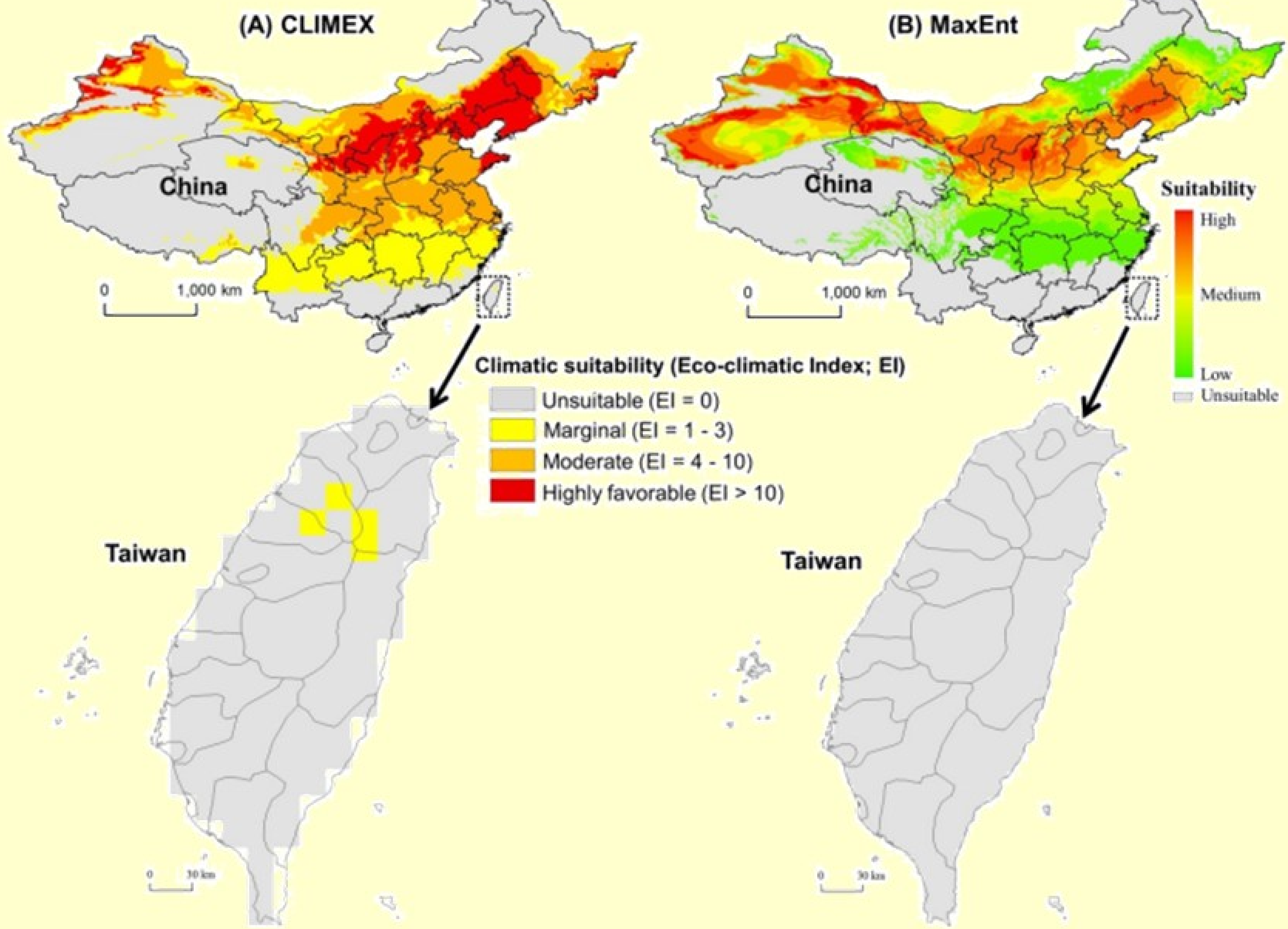
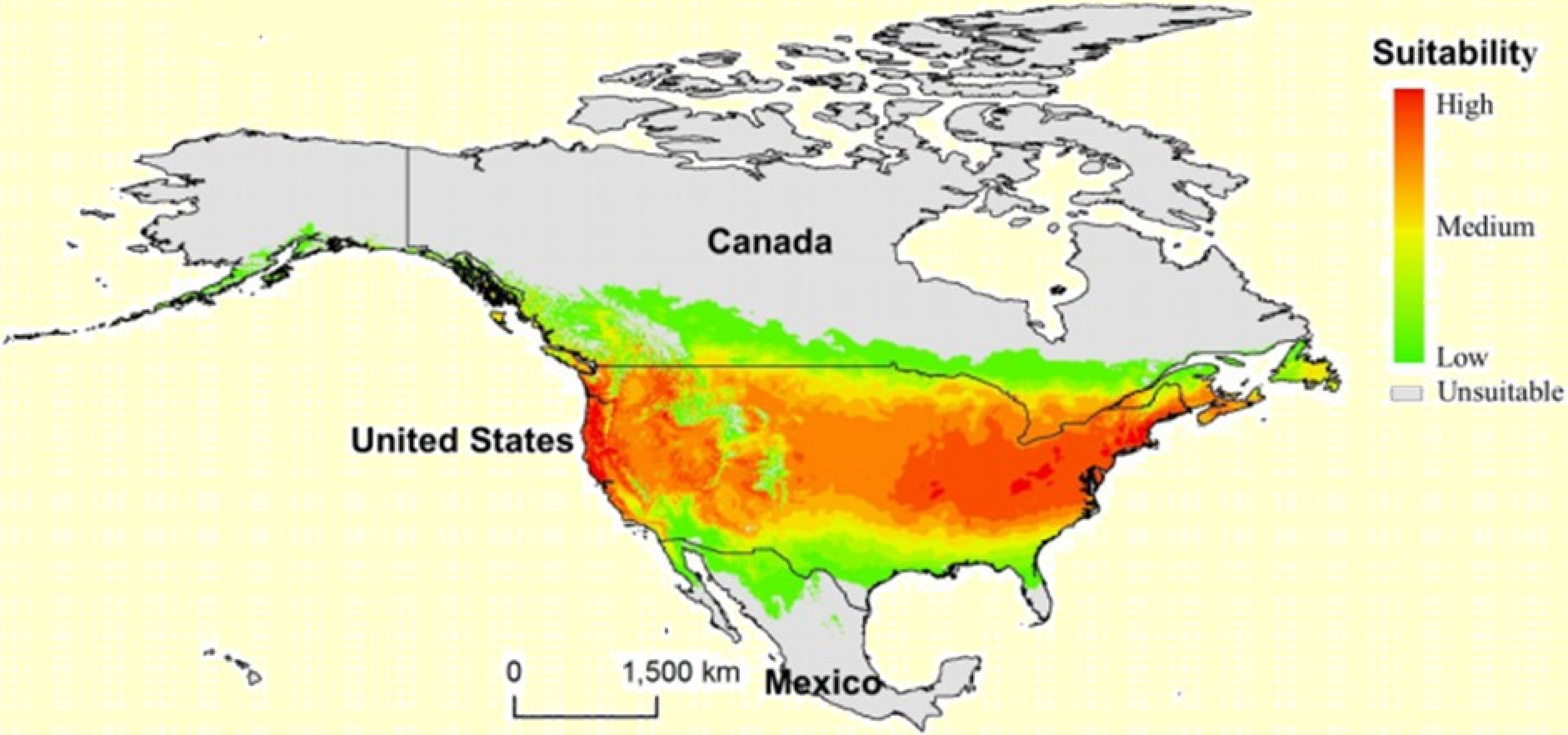


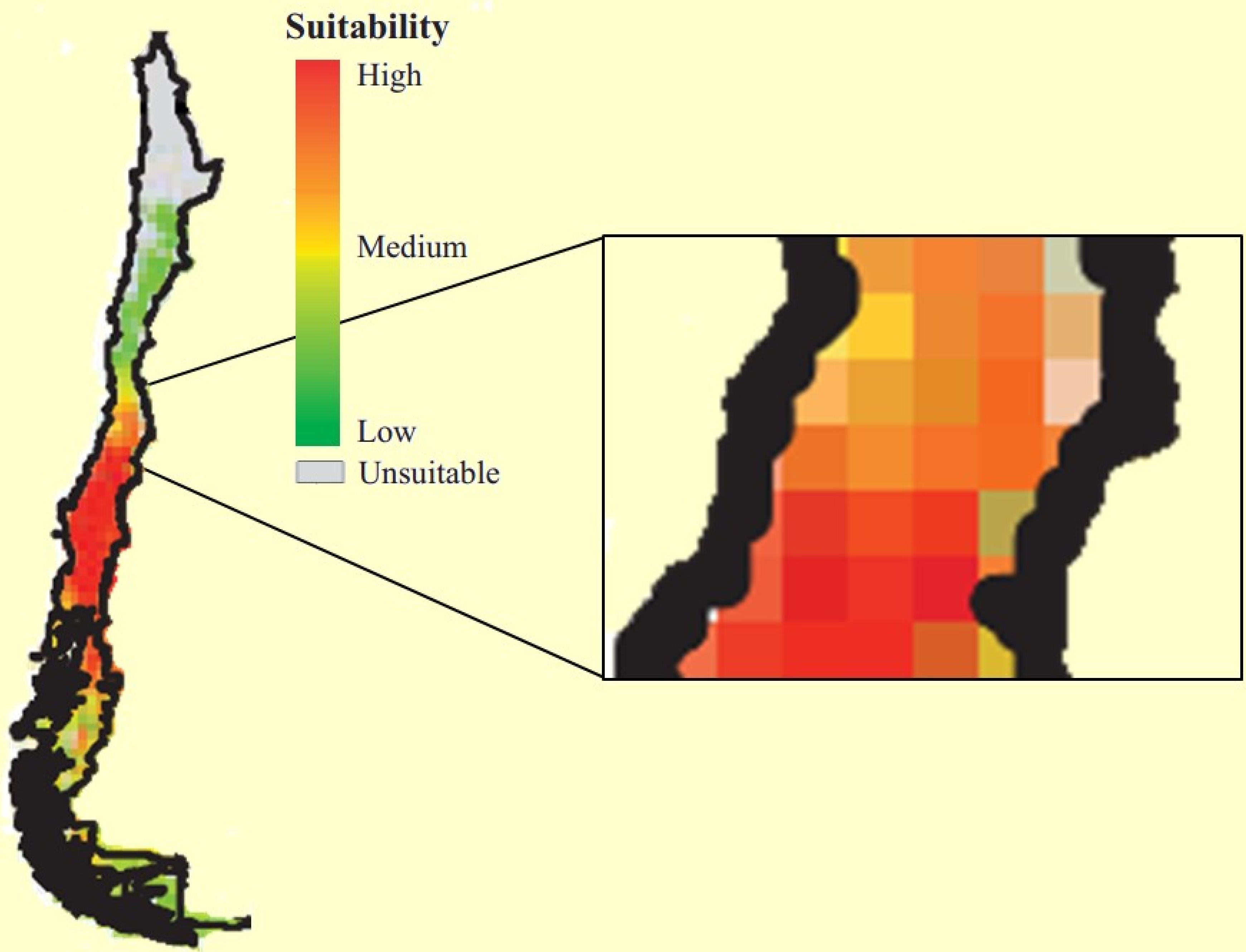
Fig. 2. Global risk of establishment of codling moth using CLIMEX model.



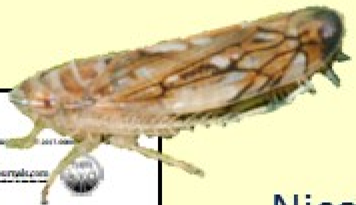
(A) CLIMEX
(B) MaxEnt
China
China
0
1,000 km
0
1,000 km
Climatic suitability (Eco-climatic Index; EI)
Unsuitable (EI = 0)
Marginal (EI = 1 - 3)
Moderate (EI = 4 - 10)
Highly favorable (EI > 10)
Suitability
High
Medium
Low
Unsuitable
Taiwan
Taiwan
0
30 km
0
30 km

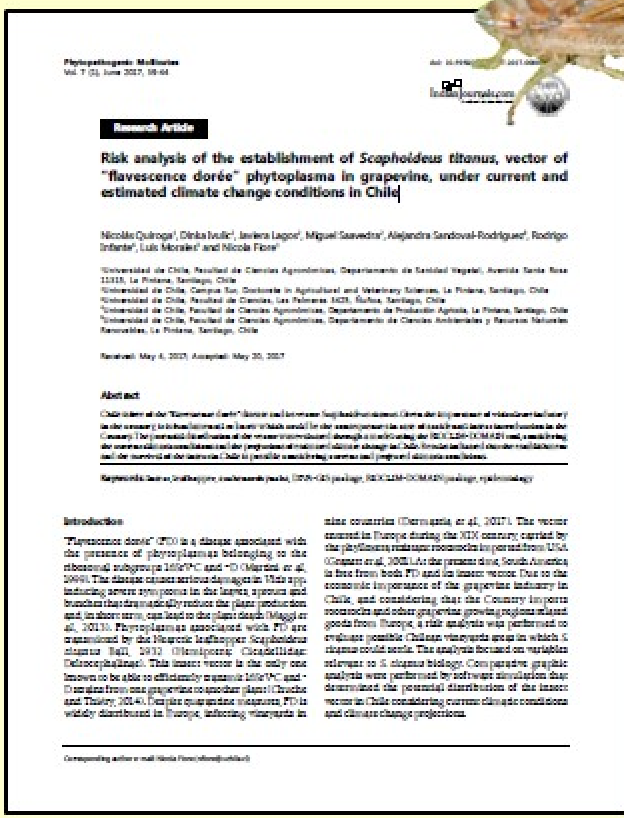


Suitability
High
Medium
Low
Unsuitable
Canada
United States
Mexico
0
1,500 km


Suitability
High
Medium
Low
Unsuitable

Risk analysis of the establishment of *Scaphoideus titanus*, vector of “flavescence dorée” phytoplasma in grapevine, under current and estimated climate change conditions in Chile




Phytopathogenic Mollicutes
Vol. 7 (1), June 2017, 59-64

Research Article

Risk analysis of the establishment of *Scaphoideus titanus*, vector of "flavescence dorée" phytoplasma in grapevine, under current and estimated climate change conditions in Chile

Nicolás Quiroga, Dinka Ivulic, Javiera Lagos, Miguel Saavedra, Alejandra Sandoval-Rodríguez, Rodrigo Infante, Luis Morales and Nicola Fiore

Abstract

Introduction

Nicolás Quiroga, Dinka Ivulic, Javiera Lagos, Miguel Saavedra, Alejandra Sandoval-Rodríguez, Rodrigo Infante, Luis Morales and Nicola Fiore

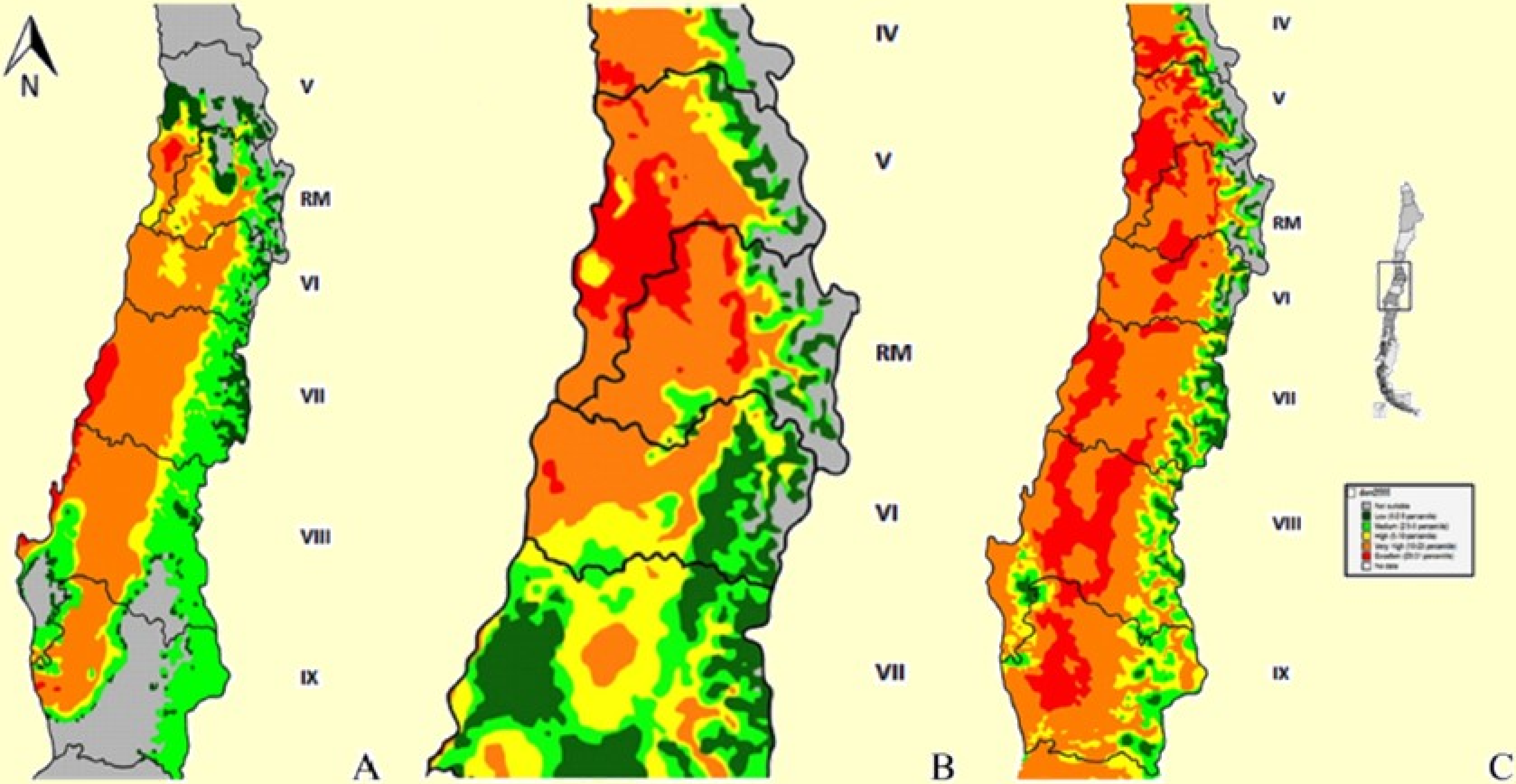
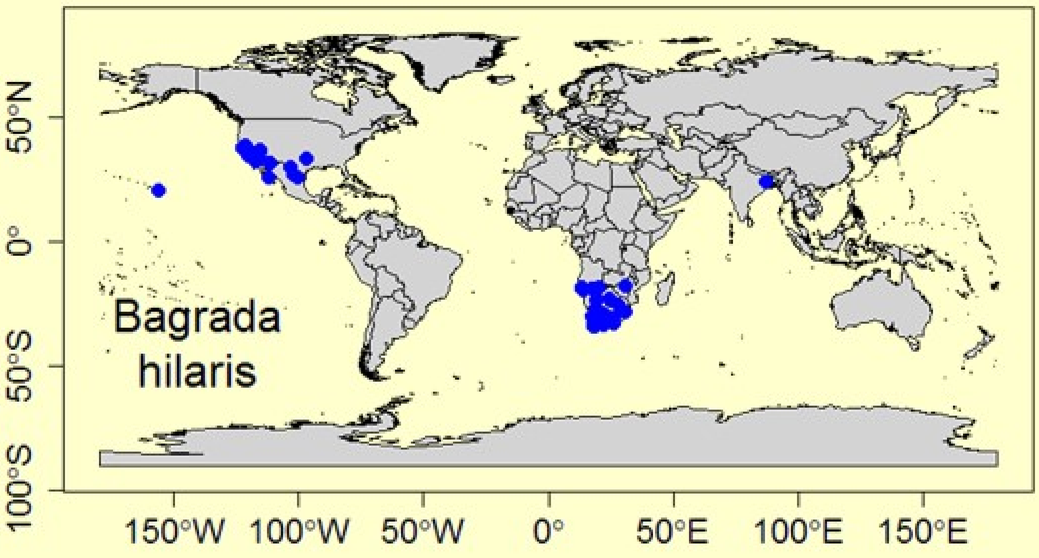


Figure 3. Potential space distribution of *S. titanus* in South-Central area of Chile under: A) current climate conditions; B) climate conditions projected by the optimistic climate change scenario; C) climate conditions projected by the pessimistic climate change scenario. Gray: not suitable areas; dark green: low probability of suitability; light green: medium probability of suitability; yellow: high probability of suitability; orange: very high probability of suitability; red: excellent probability of suitability.Chilean regions: IV, Coquimbo; V, Valparaíso; RM, Metropolitana; VI, O'Higgins; VII, Maule; VIII: Biobío; IX, Araucanía.

Modelamiento de Nicho Ecológico para B. hilaris

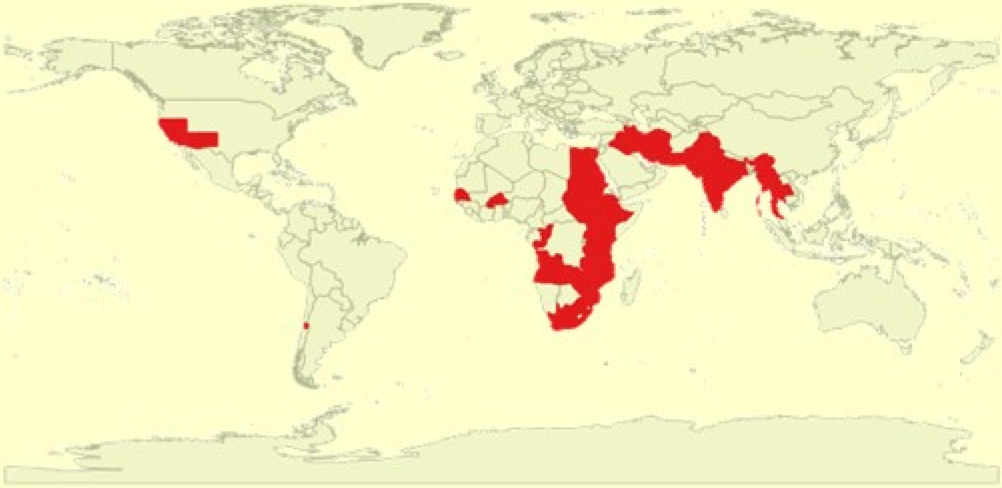


Modelos Utilizados: Maxent, Bioclim y Domain

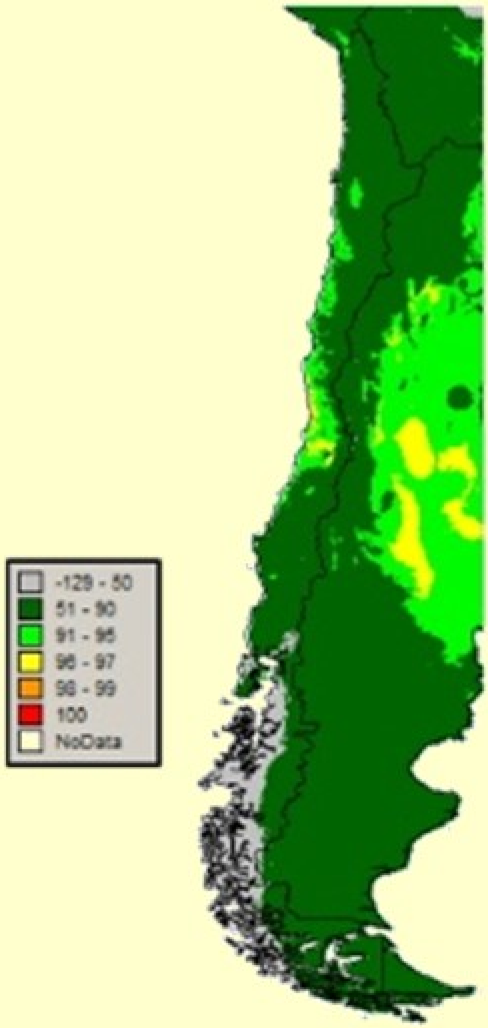
Base Bioclimática: Worldclim (variables bioclimáticas)

Presencias internacionales: Presencias nacionales: Comunas positivas

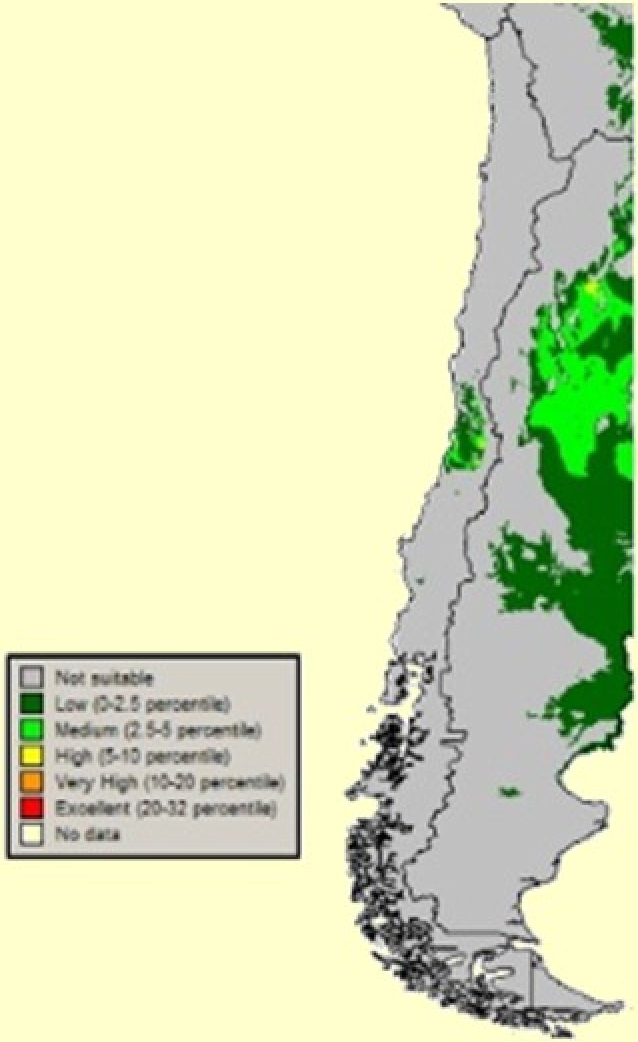
Modelos de Nicho: Permite determinar que tan idóneo o apropiado es un territorio climáticamente para el establecimiento de un individuo.



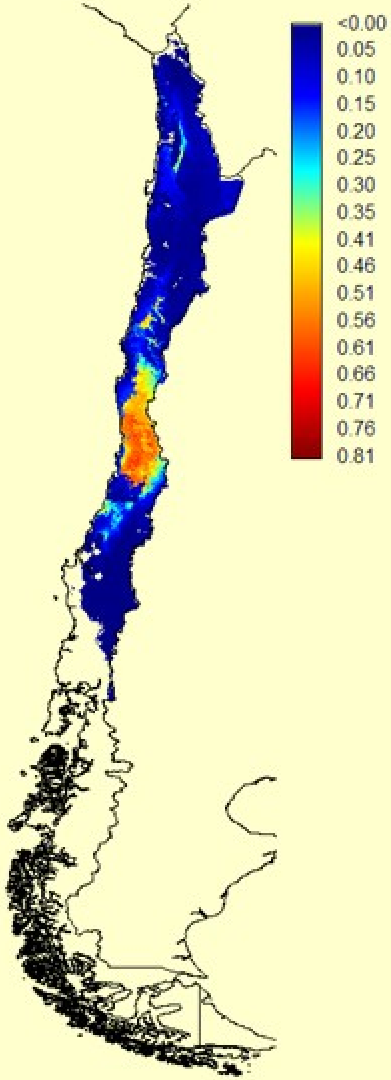
Modelos de Nicho: Permite determinar que tan idóneo es un territorio para el establecimiento de un individuo



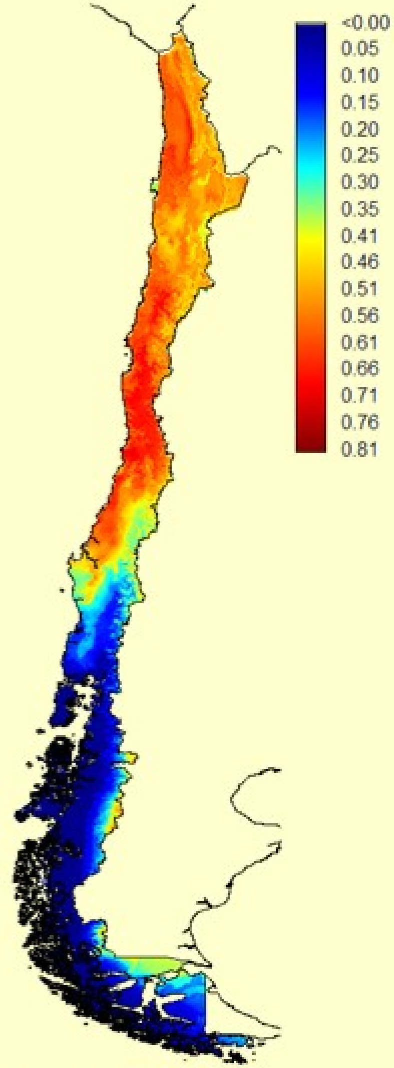
Modelo: DOMAIN



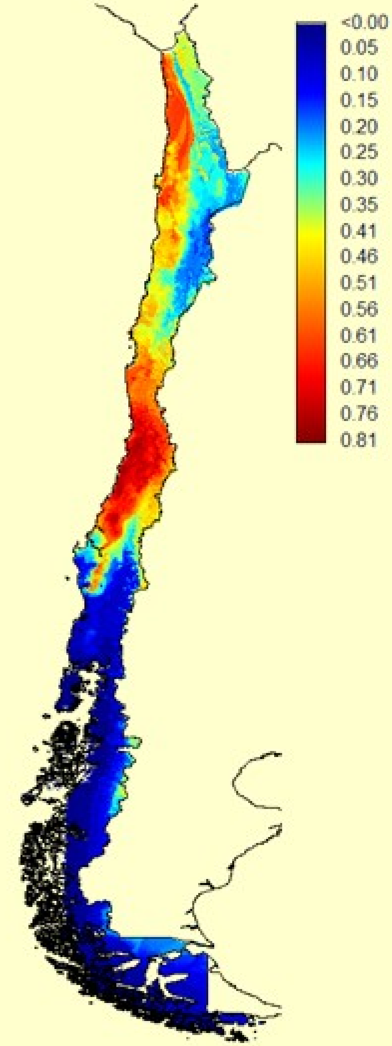
Modelo: BIOCLIM



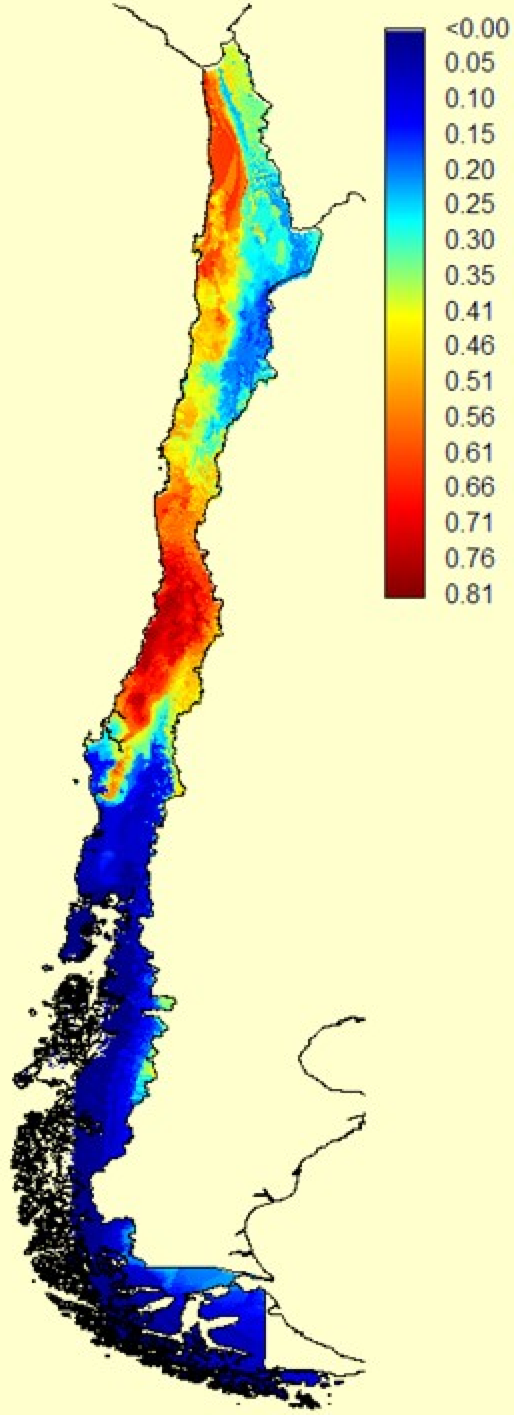
Modelo: MAXENT
N° variables Worldclim: 8
Análisis: Nacional
Presencias: comunas
Pseudo presencias: 200
Pseudo ausencias: 2000
Replicas: 25



Modelo: MAXENT
N° variables Worldclim: 8
Análisis: Nacional/Inter.
Presencias: comunas
Pseudo presencias: 6000
Pseudo ausencias: 50,000
Replicas: 25



Modelo: MAXENT
N° variables: 19
Análisis: Nacional/Inter.
Presencias: comunas
Pseudo presencias: 6000
Pseudo ausencias: 50,000
Replicas: 25


<0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.41
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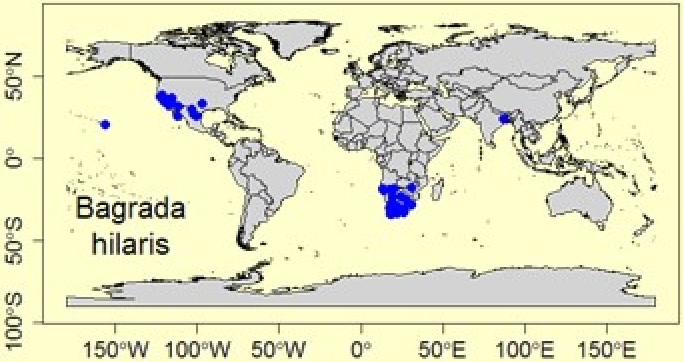
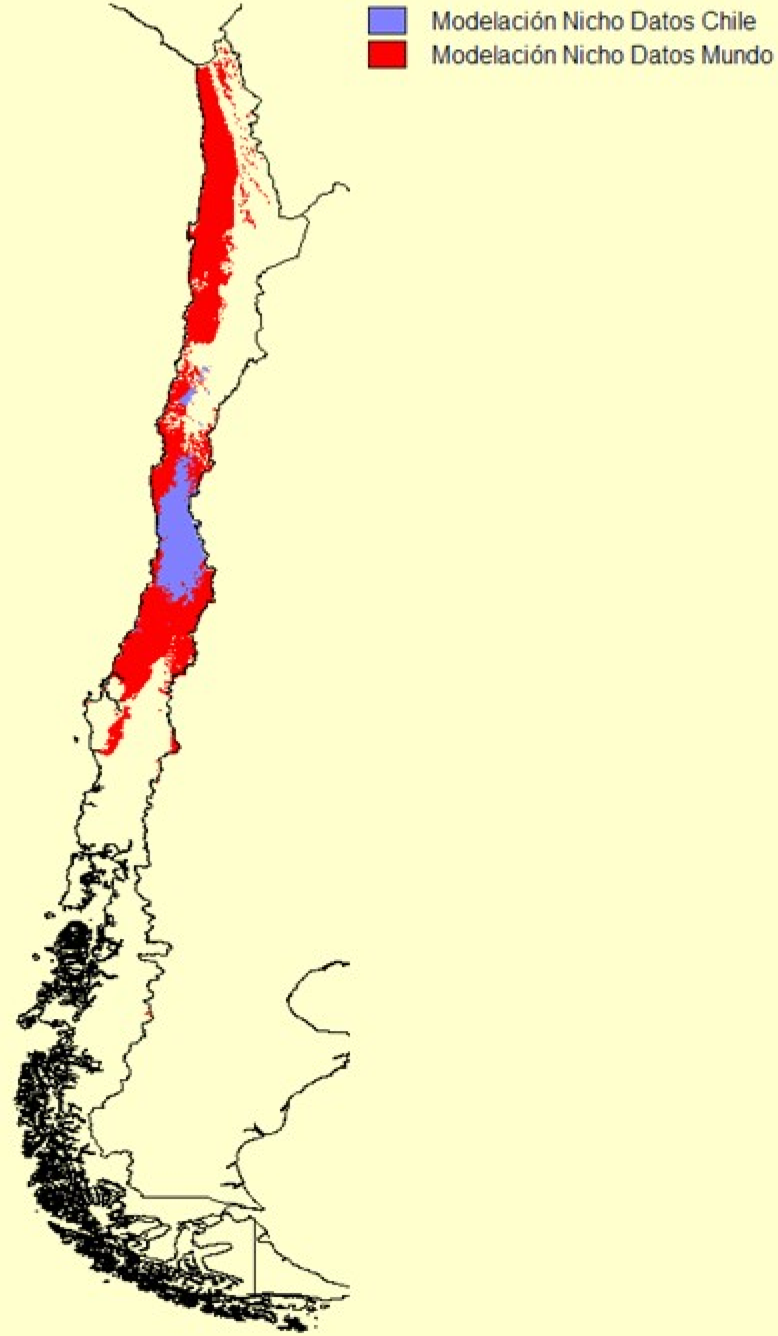
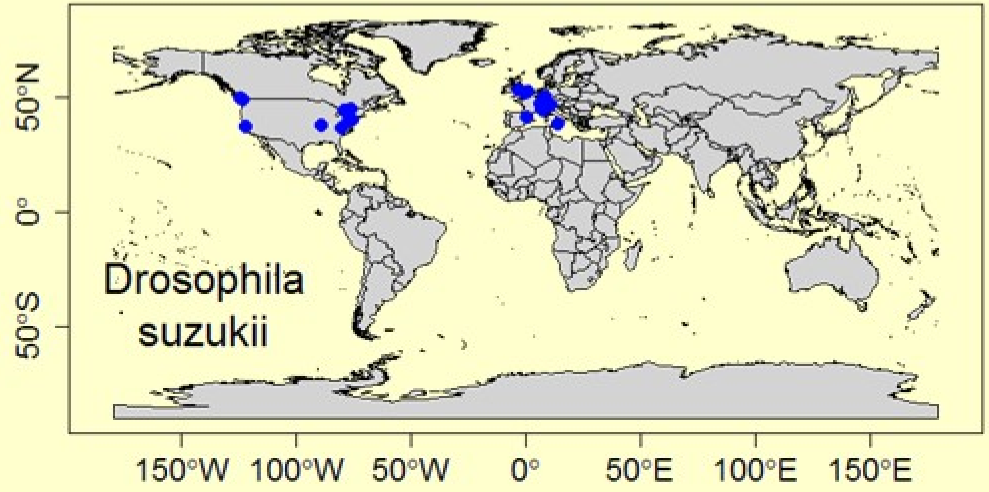
0.71
0.76
0.81


Bagrada
hilaris
50°N
0°
50°S
100°S
150°W
100°W
50°W
0°
50°E
100°E
150°E


Modelación Nicho Datos Chile
Modelación Nicho Datos Mundo

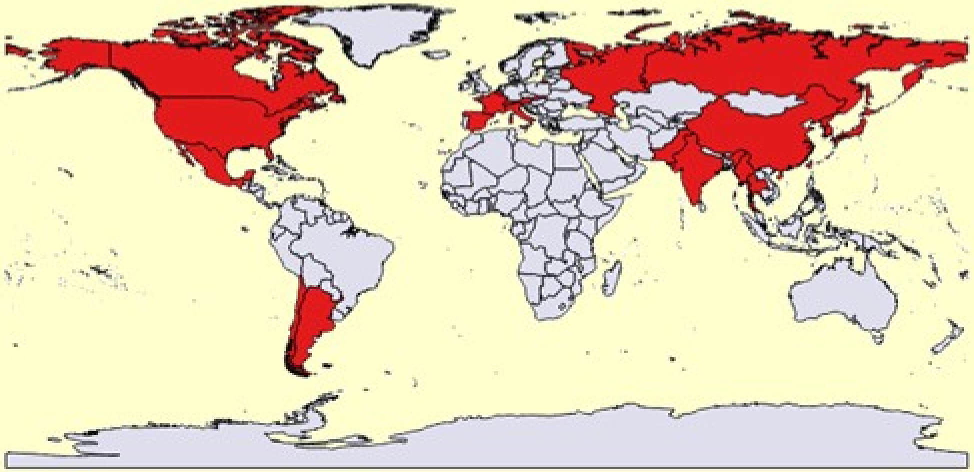
Modelamiento de Nicho Ecológico para Drosophila Suzukii

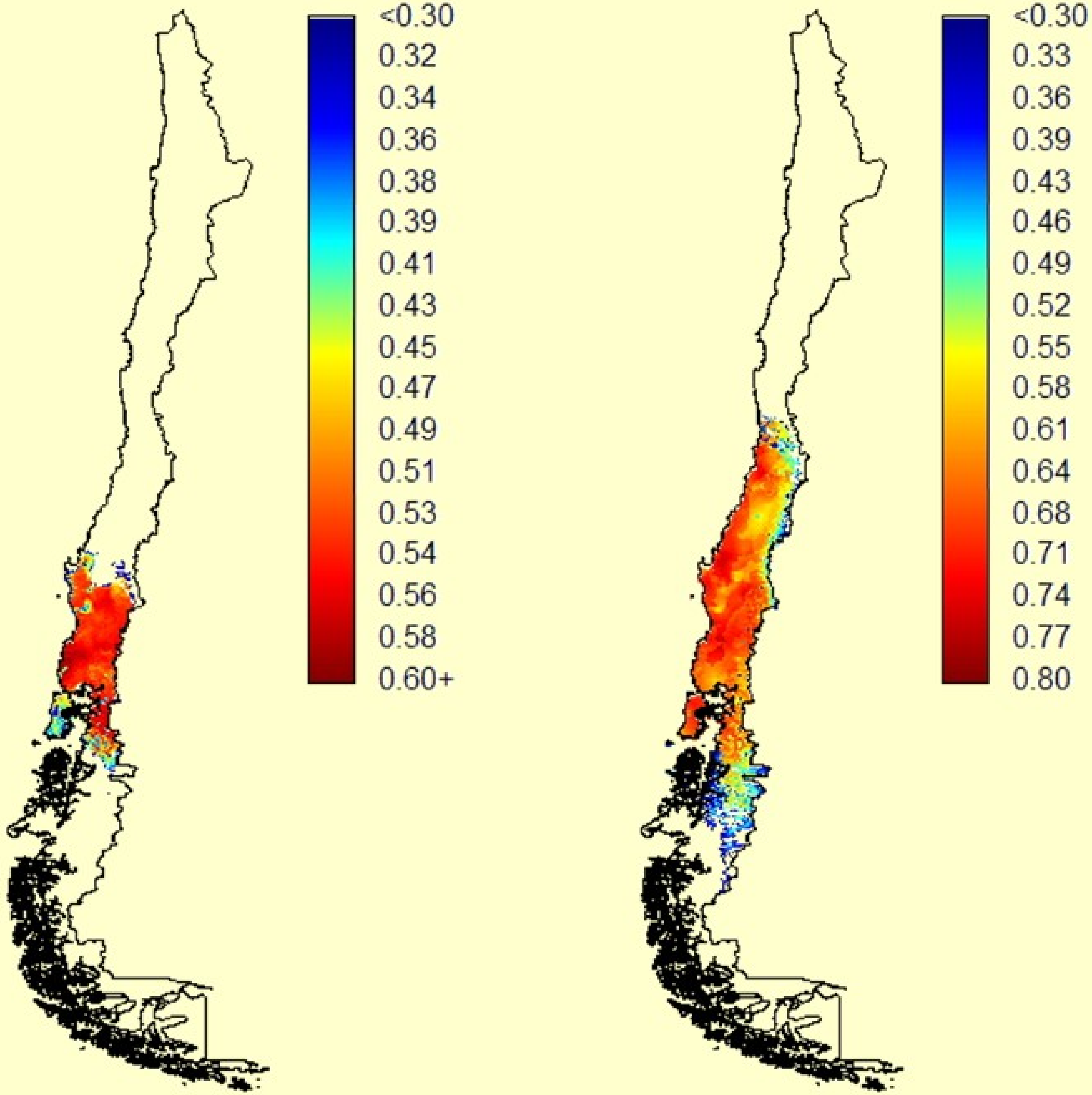


Modelos Utilizados: Maxent, Bioclim y Domain

Base Bioclimática: Worldclim (variables bioclimáticas)

Presencias internacionales: Presencias nacionales: Comunas positivas

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0.32
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0.36
0.38
0.39
0.41
0.43
0.45
0.47
0.49
0.51
0.53
0.54
0.56
0.58
0.60+
<0.30
0.33
0.36
0.39
0.43
0.46
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0.68
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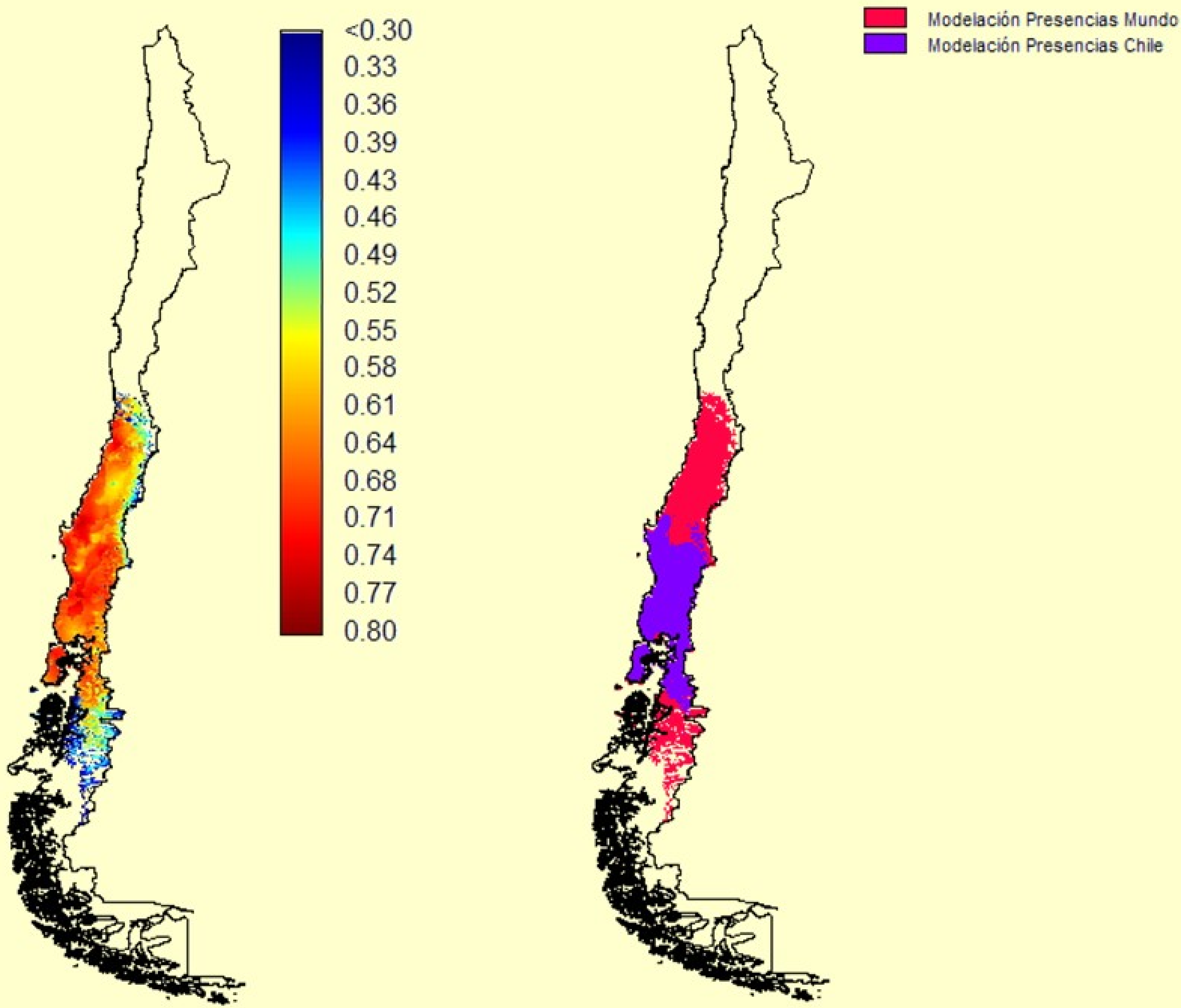
0.77
0.80



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0.33
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0.46
0.49
0.52
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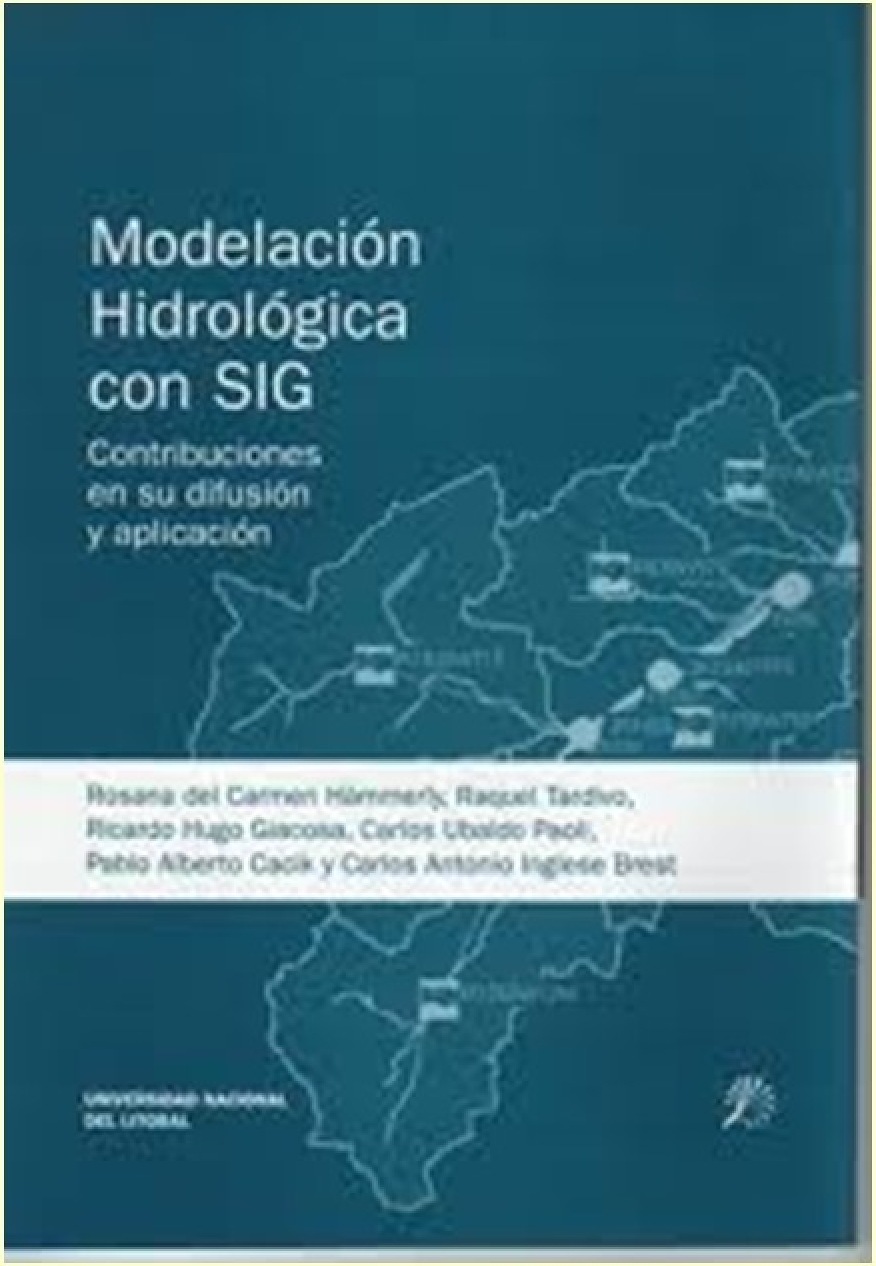
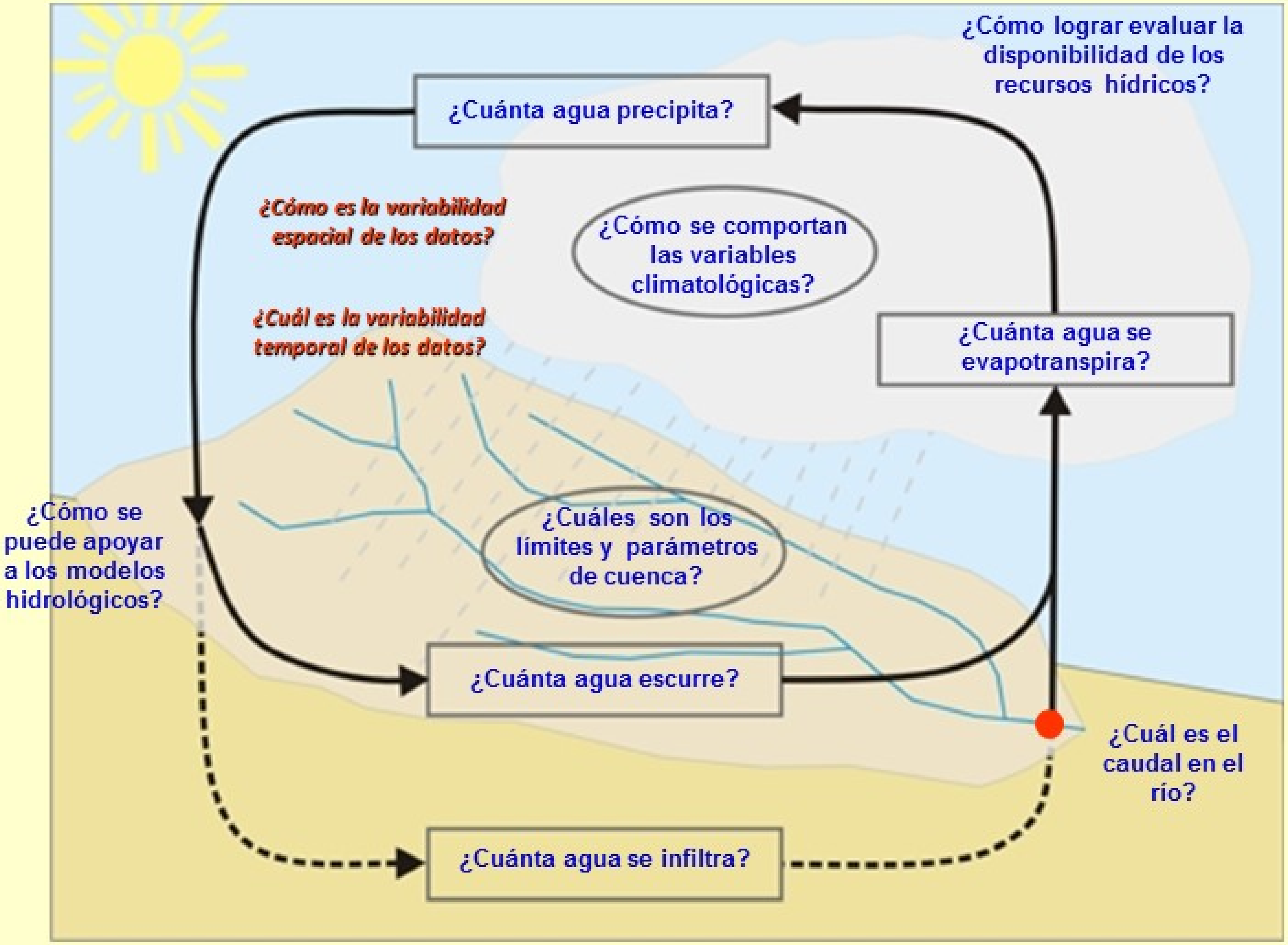
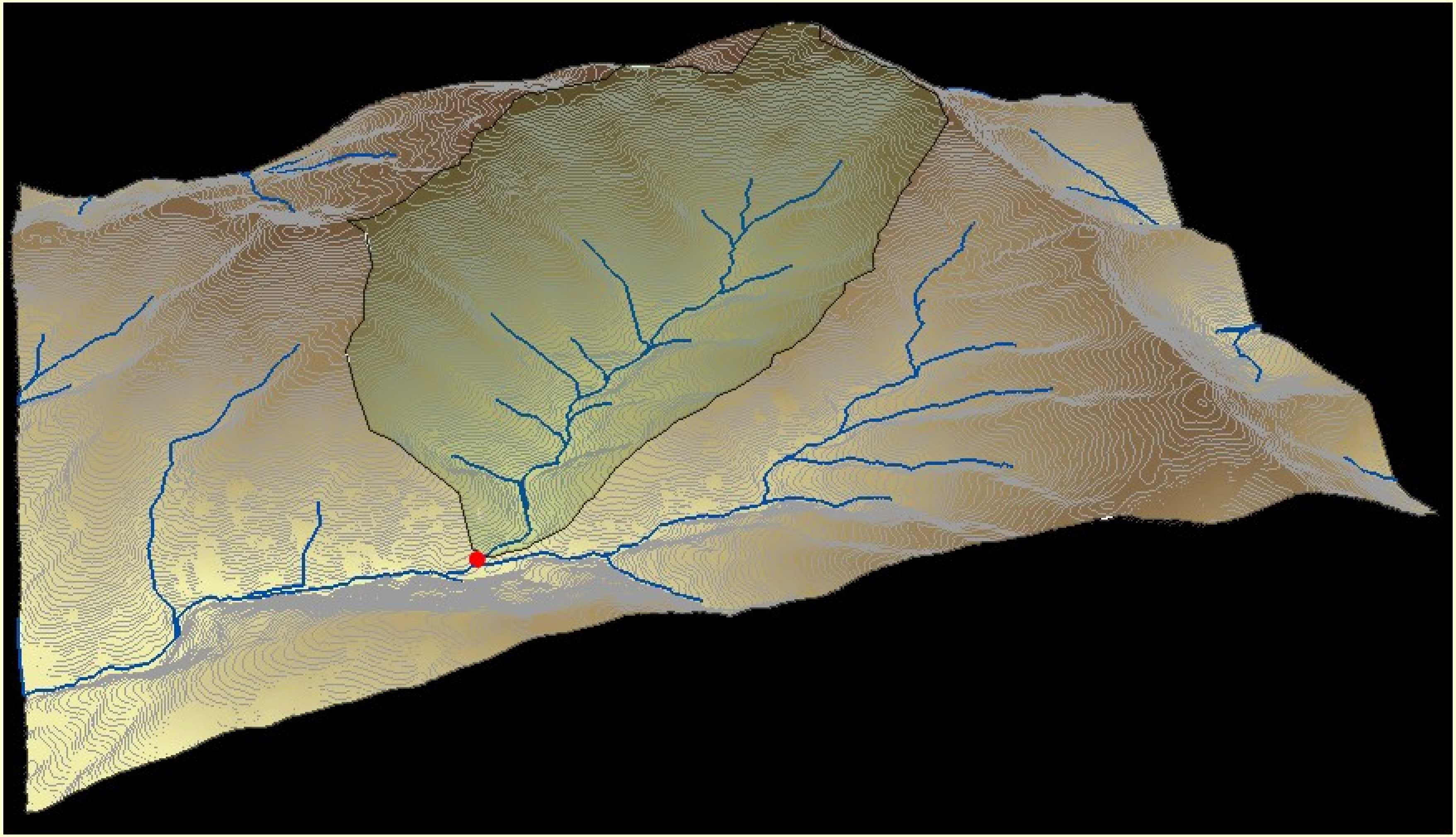
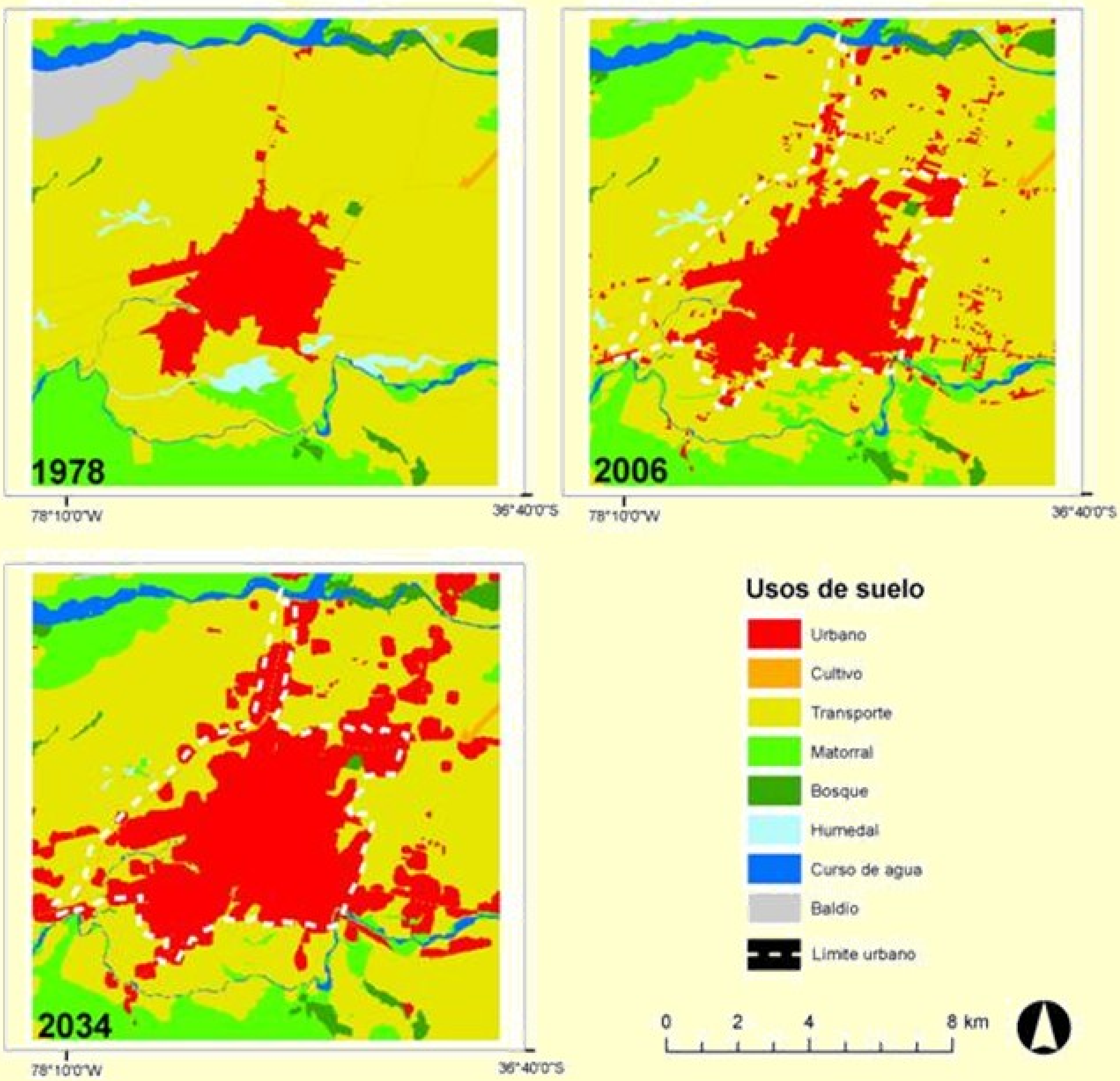
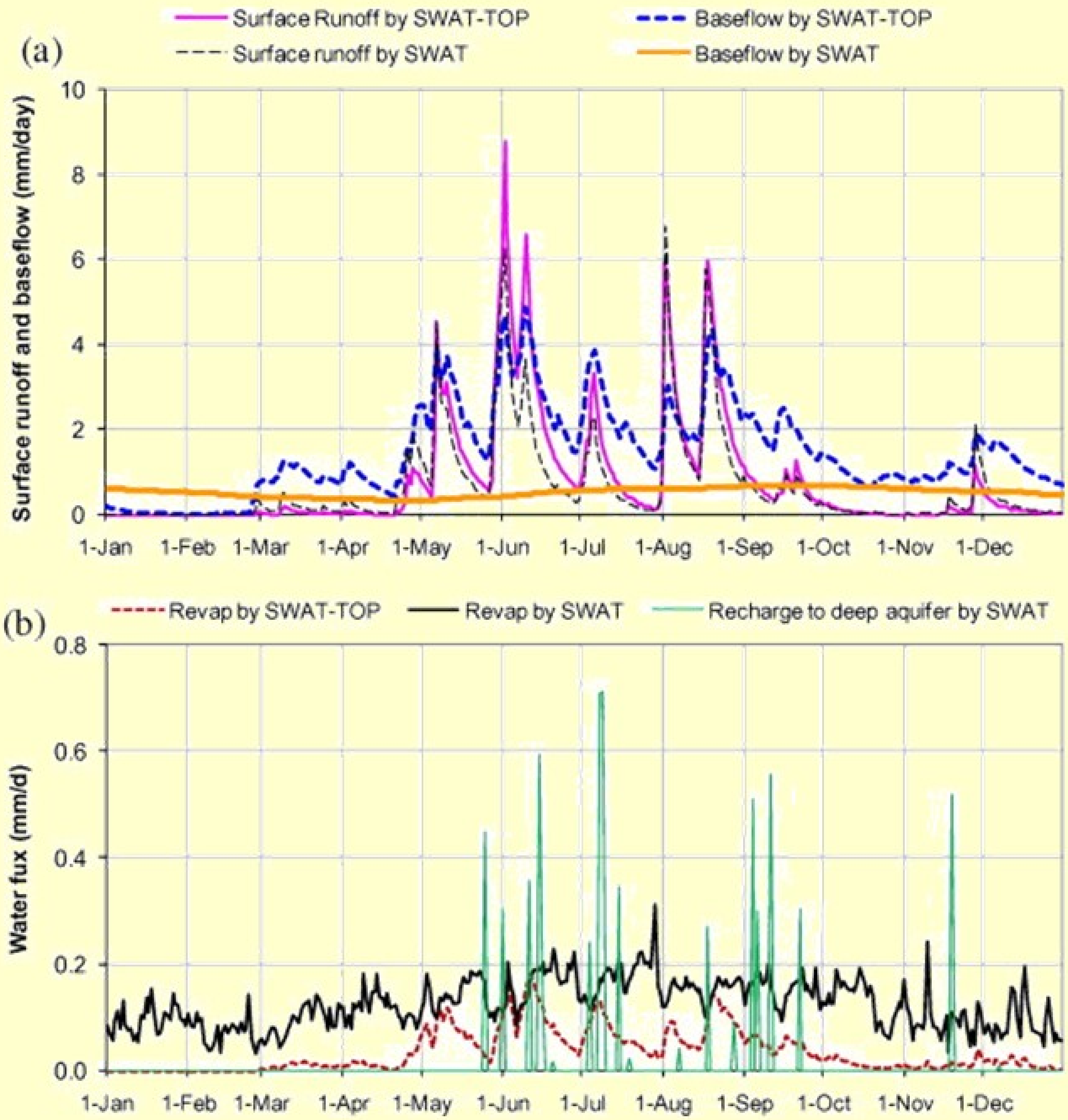
0.68
0.71
0.74
0.77
0.80
Modelación Presencias Mundo
Modelación Presencias Chile


Modelación Hidrológica con SIG
Contribuciones en su difusión y aplicación
Rosana del Carmen Hämmerly, Raquel Tardivo,
Ricardo Hugo Giacosa, Carlos Ubaldo Paoli,
Pablo Alberto Cacik y Carlos Antonio Inglese Brest
UNIVERSIDAD NACIONAL DEL LITORAL

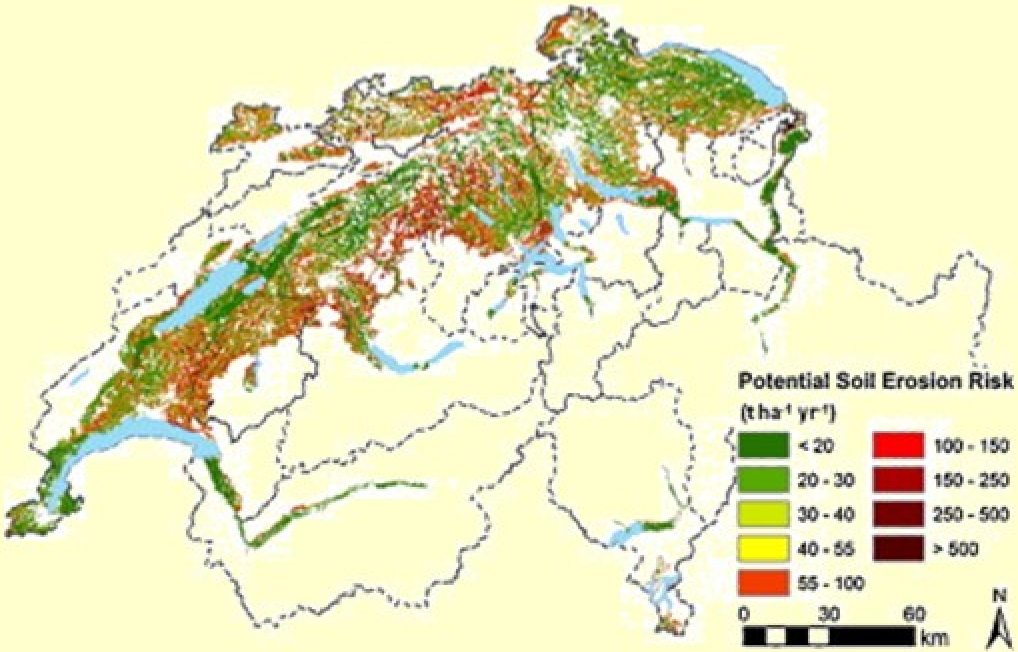

¿Cómo lograr evaluar la disponibilidad de los recursos hídricos?
¿Cuánta agua precipita?
¿Cómo es la variabilidad espacial de los datos?
¿Cómo se comportan las variables climatológicas?
¿Cuál es la variabilidad temporal de los datos?
¿Cuánta agua se evapotranspira?
¿Cómo se puede apoyar a los modelos hidrológicos?
¿Cuáles son los límites y parámetros de cuenca?
¿Cuánta agua escurre?
¿Cuál es el caudal en el río?
¿Cuánta agua se infiltra?

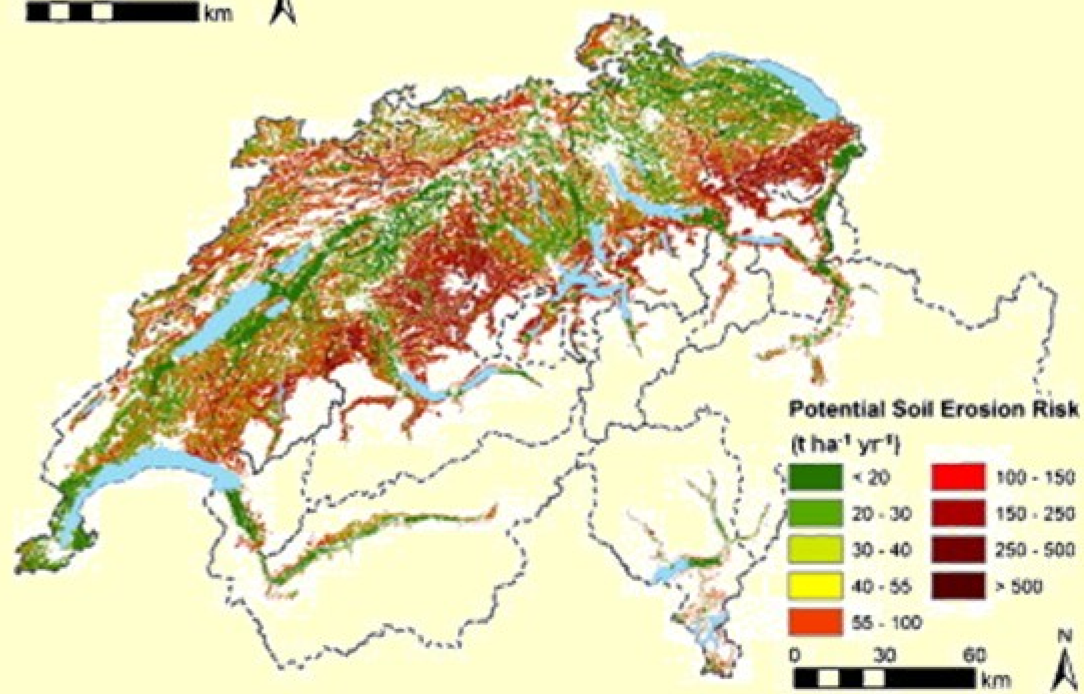



1978
2006
2034
78°10'0"W
36°40'0"S
78°10'0"W
36°40'0"S
78°10'0"W
36°40'0"S
Usos de suelo
Urbano
Cultivo
Transporte
Matorral
Bosque
Humedal
Curso de agua
Baldío
Límite urbano
0
2
4
8 km

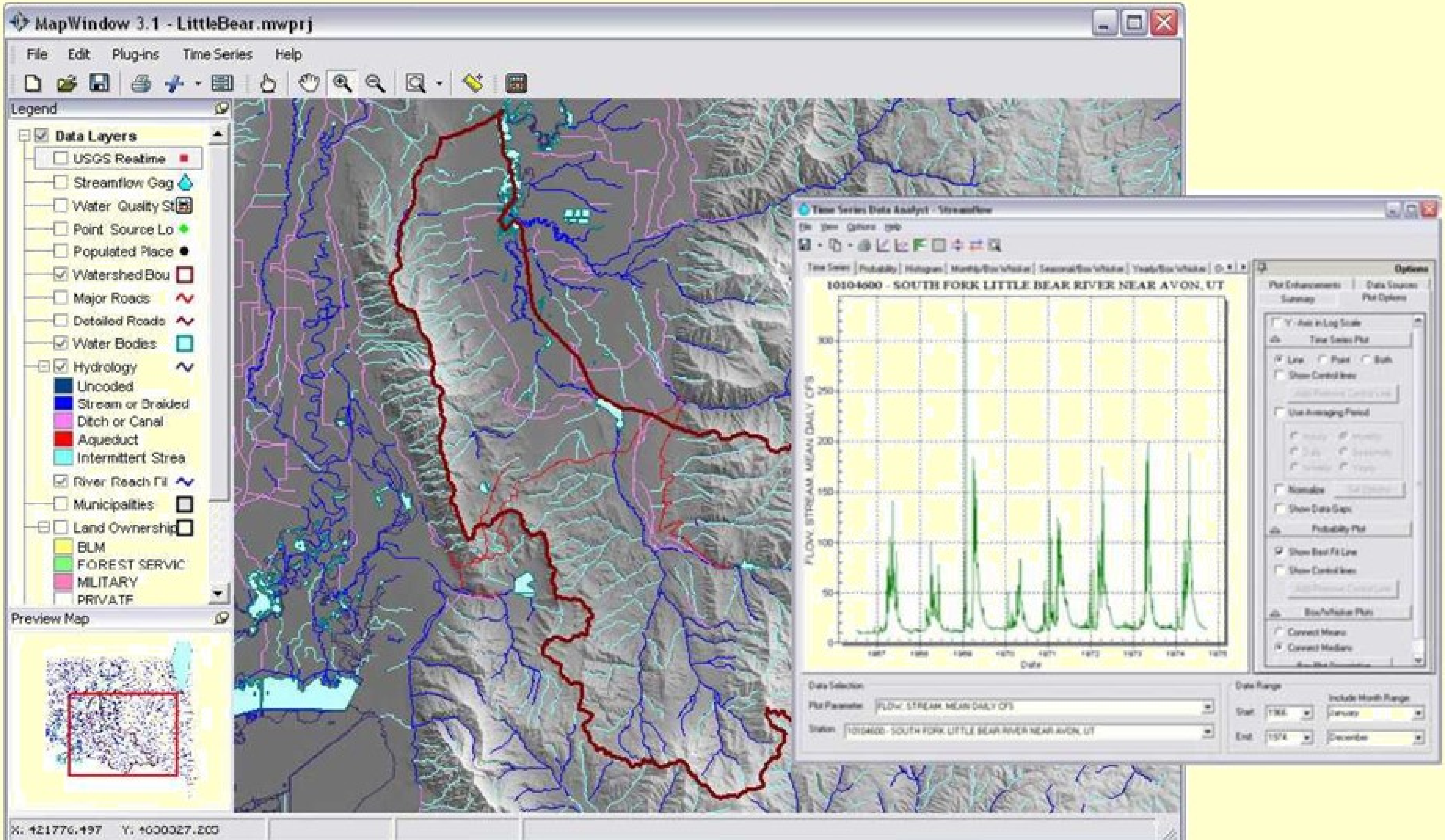


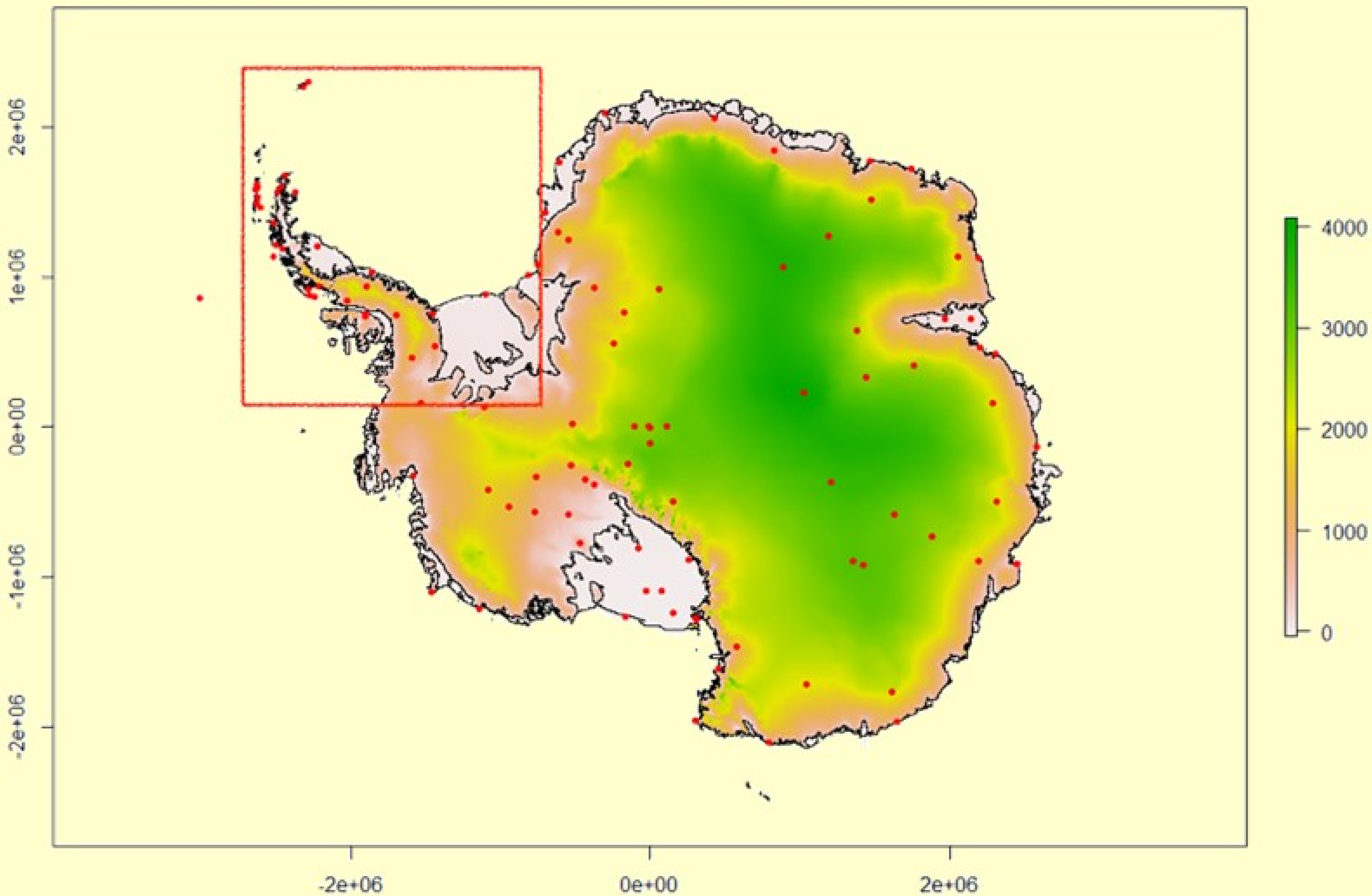
(a)
Surface Runoff by SWAT-TOP
Baseflow by SWAT-TOP
Surface runoff by SWAT
Baseflow by SWAT
Surface runoff and baseflow (mm/day)
0
2
4
6
8
10
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
(b)
Revap by SWAT-TOP
Revap by SWAT
Recharge to deep aquifer by SWAT
Water flux (mm/d)
0.0
0.2
0.4
0.6
0.8
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec


Potential Soil Erosion Risk
(t ha-1 yr-1)
< 20
20 - 30
30 - 40
40 - 55
55 - 100
100 - 150
150 - 250
250 - 500
> 500
0 30 60
km
N


Potential Soil Erosion Risk
(t ha-1 yr-1)
< 20
20 - 30
30 - 40
40 - 55
55 - 100
100 - 150
150 - 250
250 - 500
> 500
0 30 60
km
N

OpenNSPECT


MapWindow 3.1 - LittleBear.mwprj
File
Edit
Plug-ins
Time Series
Help
Legend
Data Layers
USGS Realtime
Streamflow Gag
Water Quality St
Point Source Lo
Populated Place
Watershed Bou
Major Roads
Detailed Roads
Water Bodies
Hydrology
Uncoded
Stream or Braided
Ditch or Canal
Aqueduct
Intermittent Strea
River Reach Fil
Municipalities
Land Ownership
BLM
FOREST SERVIC
MILITARY
PRIVATE
Preview Map
X: 421776.497 Y: 4630327.265
Time Series Data Analyst - Streamflow
10104600 - SOUTH FORK LITTLE BEAR RIVER NEAR AVON, UT
FLOW, STREAM, MEAN DAILY CFS
Date
Options
Data Selection
Plot Parameter
Station
Date Range
Start
End



2e+06
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-1e+06
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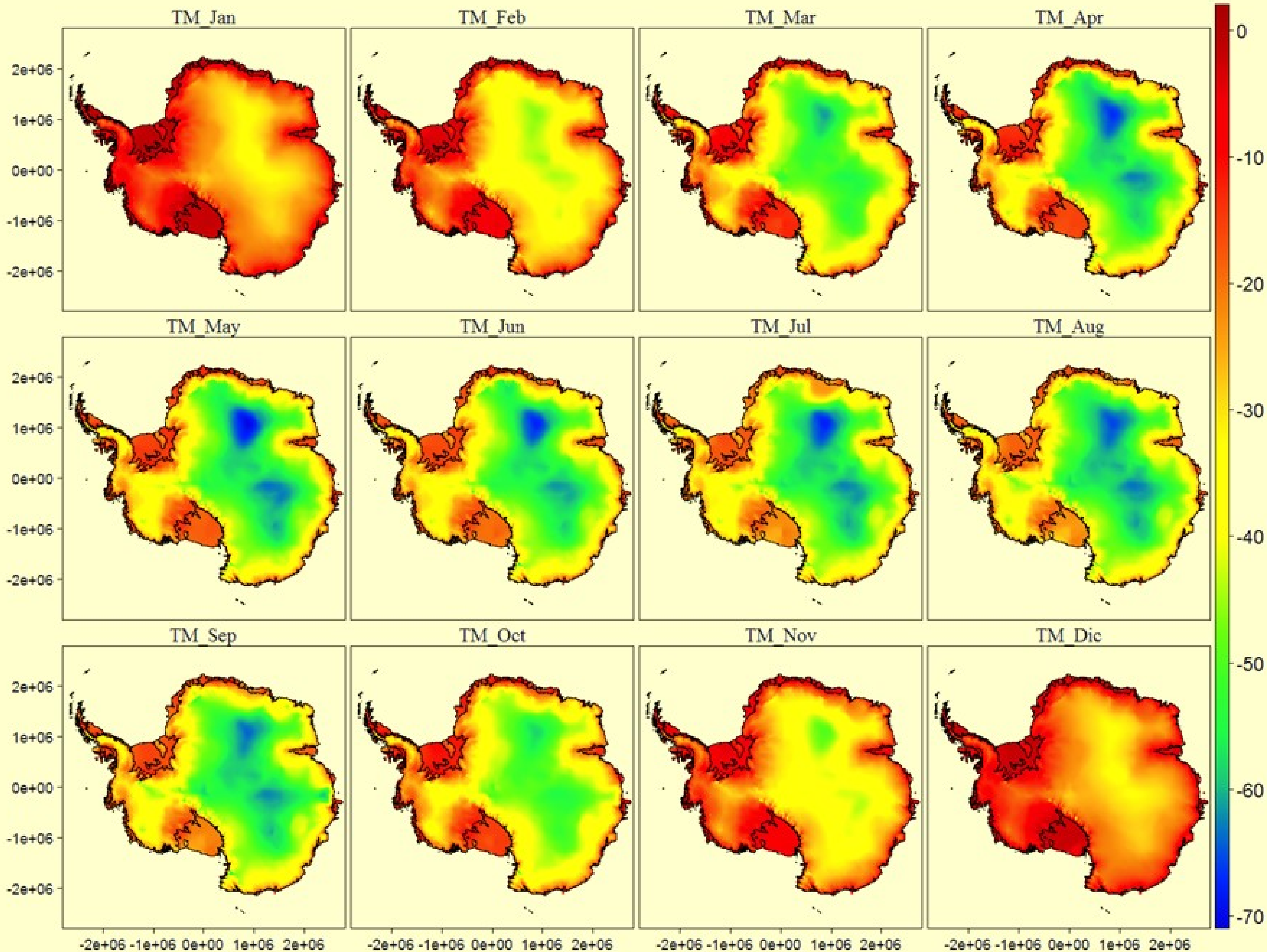
3000
2000
1000
0


TM_Jan
TM_Feb
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TM_May
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TM_Aug
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TM_Dic
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-2e+06
-2e+06 -1e+06 0e+00 1e+06 2e+06
0
-10
-20
-30
-40
-50
-60
-70

Adapting agricultural land management to climate change: a regional multi-objective optimization approach

GRACIAS !