Instituto Nacional de Investigación en **Salud Pública INSPI**

Conceptual framework for spatio-temporal analysis of health situation

Quito, 21th july 2016

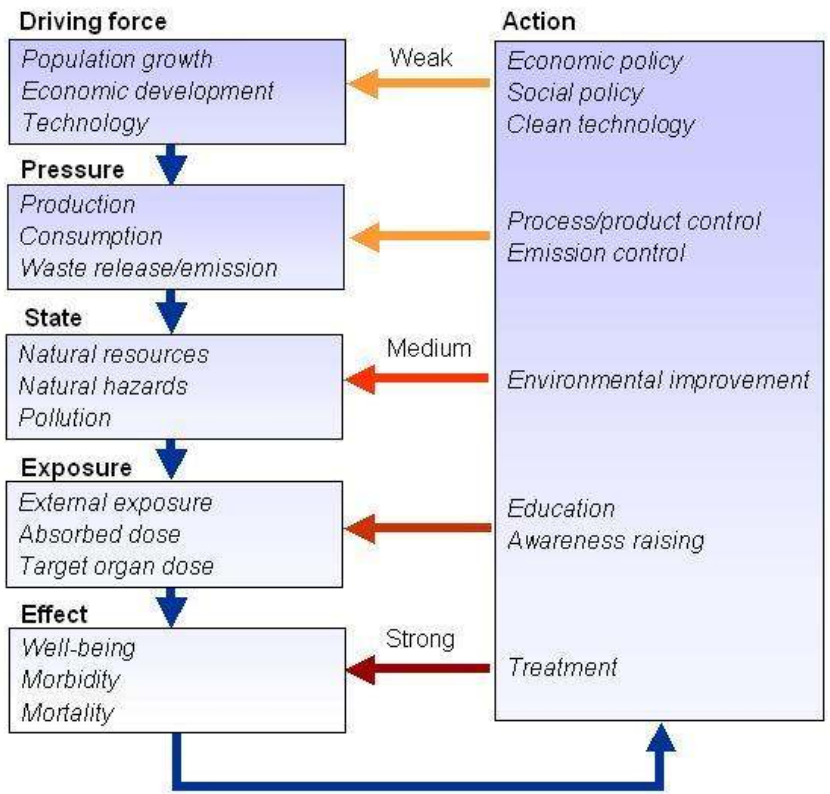
EpiSIG

Plataforma integrada de epidemiología, geomática, bioinformática y bioestadística. del INSPI

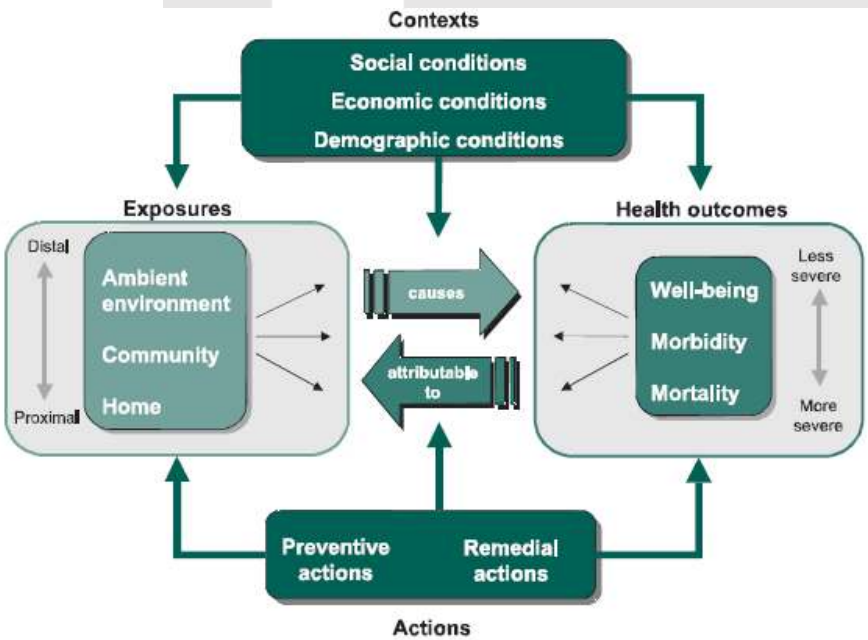
Antecedents

- Existing conceptual frameworks in environmental health:
  - Driving Force-Pressure-State-Exposure-Effect-Action (DPSEEA) : http://www.healthgain.eu/dpseea-framework
  - Multiple Exposures Multiple Effects (MEME) model

DPSEEA



MEME



Antecedents

- To implement those logical frameworks, there is indicators that can be calculated from available spatio-temporal variables :
  - Epidemiological measures
  - Synthetic indicators as the Global Disease Burden (GDB) evaluation
- Advanced spatial and time analysis/modeling is available through Geographic Information System (GIS)

- → need for an integrated approach

Existing spatial tools (basical)

Organización Mundial de la Salud (OMS)
HealthMapper, Global Health Atlas
http://www.who.int/health_mapping/

Organización Panamericana de la Salud (OPS)
SIG Epi
http://ais.paho.org/sigepi/

Centers for Disease Control and Prevention (CDC)
Epi Info (Epi Map)
http://www.cdc.gov/epiinfo/

Proposal

- **General objective**: development and implementation of an integrated geomatic system in order to facilitate the spatio-temporal analysis of public health related issues.

- **Development steps**
  - Identify epidemiologic/mathematic models more appropriate to health issues
  - Adapt those methods to geomatic structure
  - Implement the models into a GIS
  - Calibrate/validate the developed modules

¿What are the health related aspects that need to be analyzed?

¿In which social conditions live populations?

¿In which environmental conditions live populations?

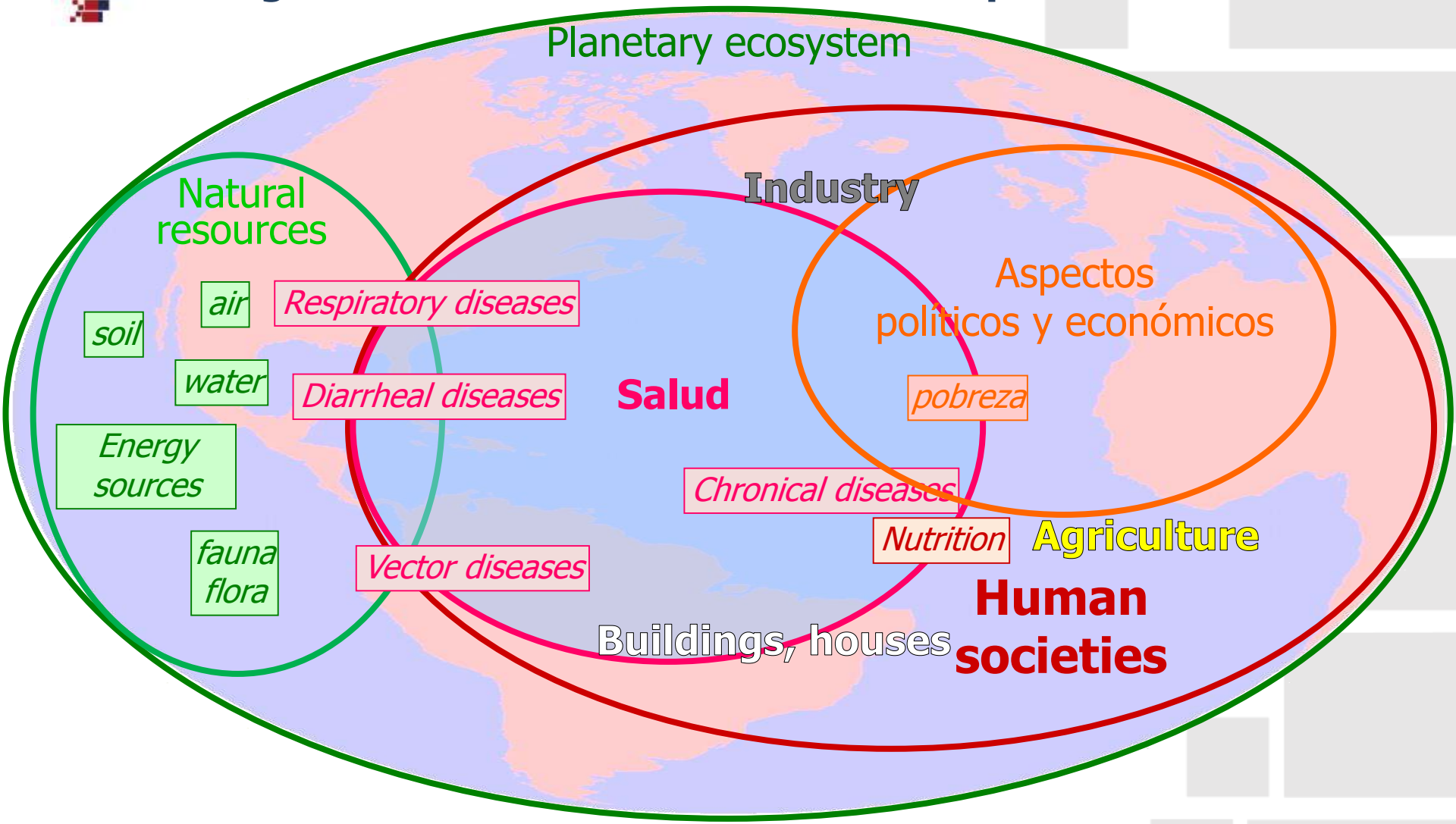
¿What is the health state of the populations?

¿How equitative decisions should be take in public health?

¿How it varies in space?

¿How it changes in time?

Integrated visión of human health to implement in GIS



Geomatic perspective : analyze and model statics and dynamic aspects with all the interrelations of this complex system, particularly from the point of view of variability in space and in time

Developing methodology

Integrated Management of **Public Health**

Spatial analysis

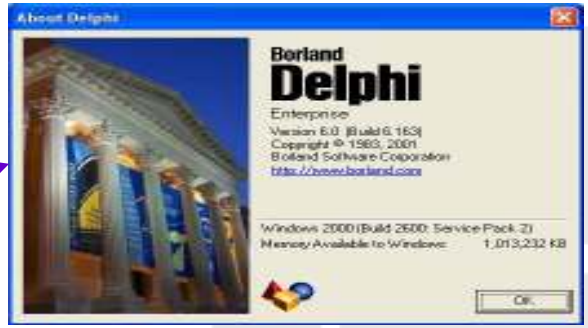
Temporal analysis

Conceptual modeling

Geomatic modeling

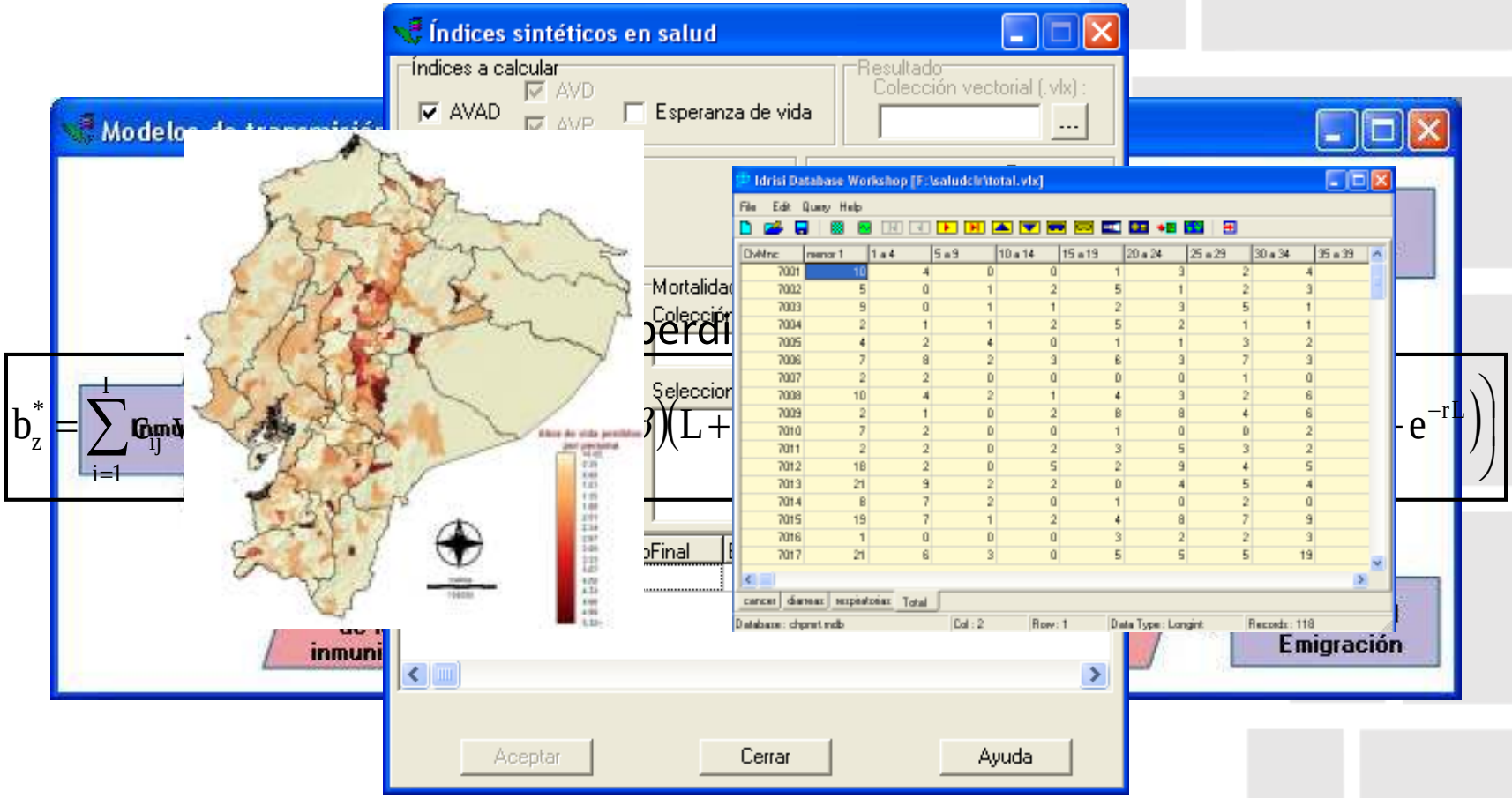
Implementation (TerrSet-Delphi)

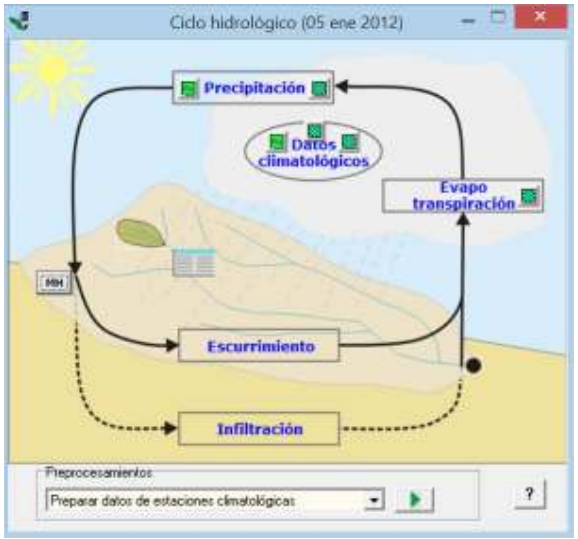
Colaboration with **Clark Labs**



Developing methodology

Conceptual modeling → Geomatic modeling → Implementation (GIS modules) → Validation (study regions)



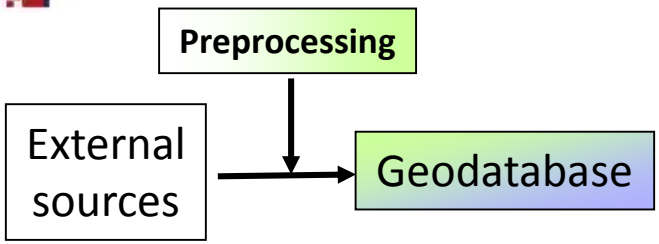

Ciclo hidrológico (05 ene 2012)
Precipitación
Datos climatológicos
Evapo transpiración
Escurrimiento
Infiltración
Preprocesamientos
Preparar datos de estaciones climatológicas

Perspectiva geomática de la gestión integrada de la salud
Gestión integrada de la salud pública
Ecosistema planetario
Recursos naturales
Industrias
Aspectos políticos y económicos
suelo
aire
enf. respiratorias
agua
enf. diarreicas
Salud
pobreza
fuentes de energía
enf. crónicas
nutrición
Agricultura
fauna flora
enf. por vectores
Sociedades humanas
Perspectiva geomática para analizar y modelar los aspectos estáticos y dinámicos de este sistema complejo, en particular desde el punto de vista de la variabilidad espacial así como temporal.
EpiSIG

Cadena de infección (12 mar 2015)
Fuentes de contaminación Reservorios
Servicios en agua y salud
Riesgo compuesto
Exposición
Medidas de salud
Estructura
Preprocesar

Agua-Población (2 jun 2011)
Características demográficas
Características del uso de agua
Evaluación

Efficient database structure



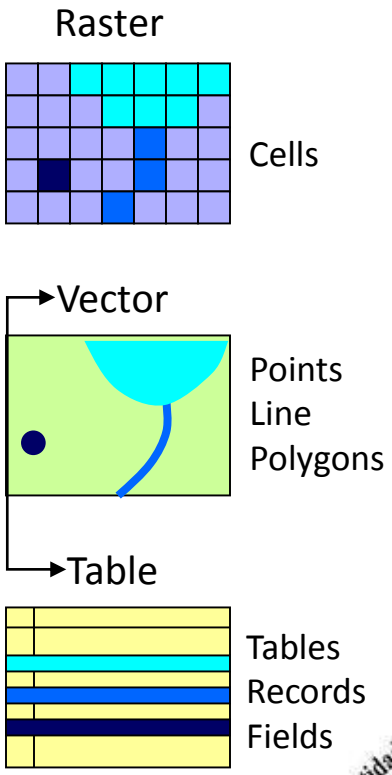
Institution that compile data (tables):

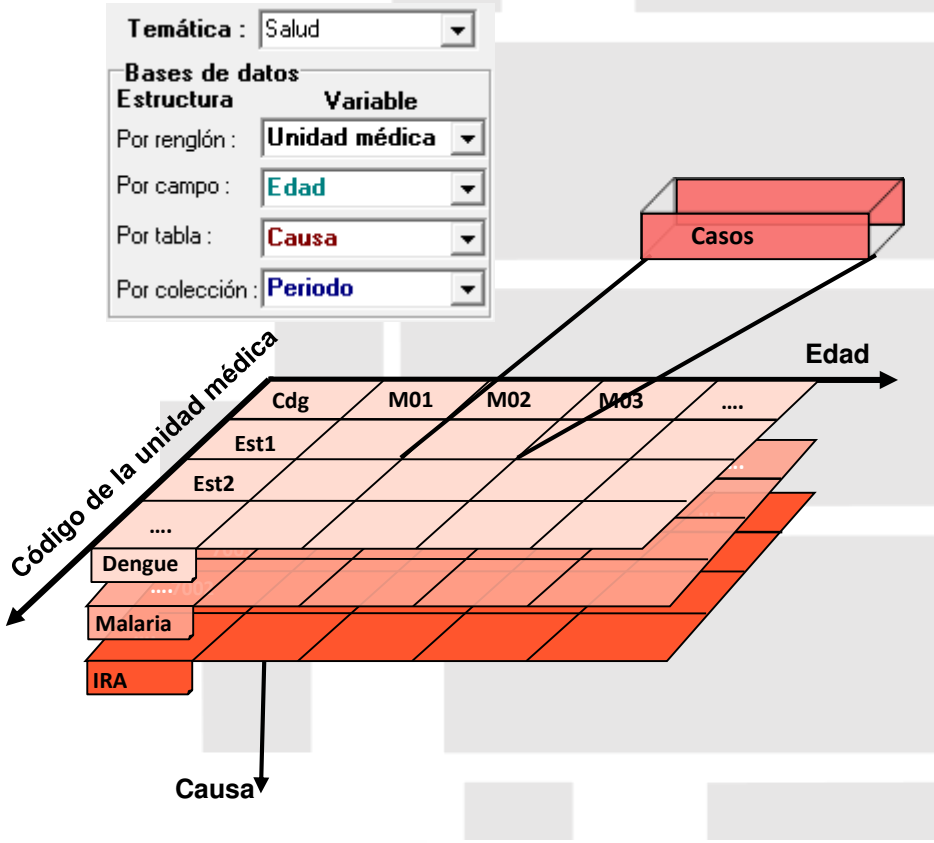
- climatologic

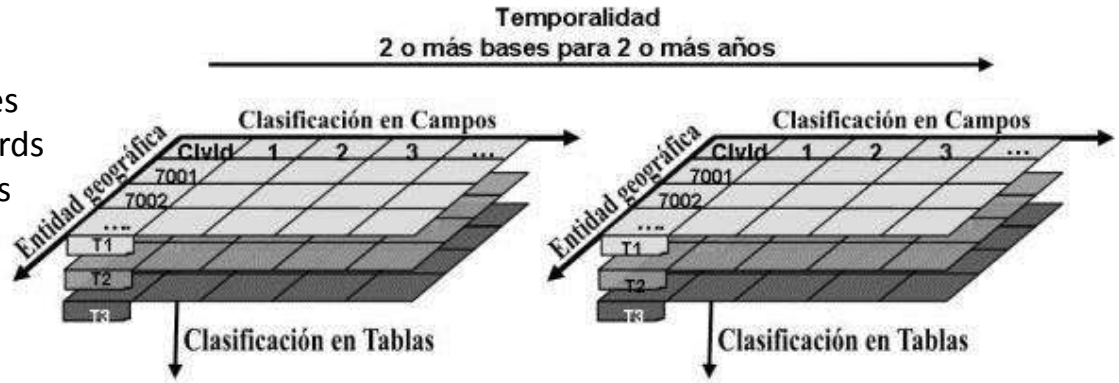
- census

- health

→ various formats

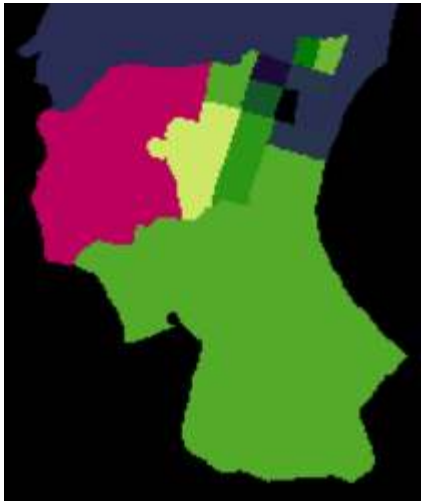




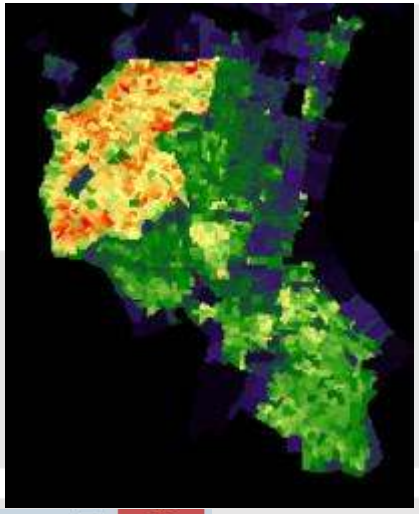


Preprocessing modules

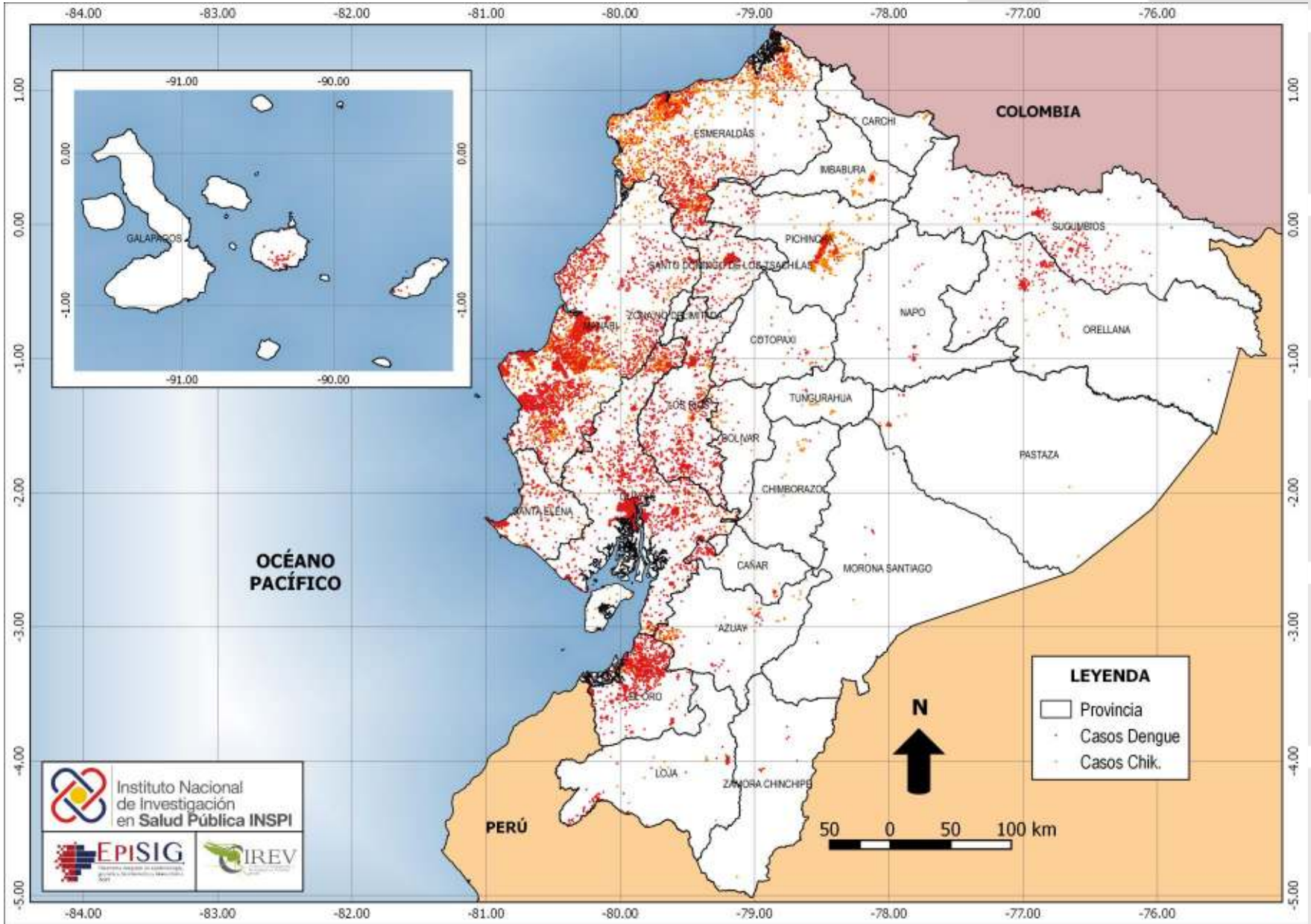
UNI_CODI_A	Provincia	Canton	Unidad operi	SumaDeTota
91	AZUAY	CAMILO PONCE	PONCE ENRIQU	56
92	AZUAY	CAMILO PONCE	ZHUMIRAL	13
1306	MANABI	MANTA	20 DE MAYO	6
1304	MANABI	MANTA	SAN JOSE	4
1305	MANABI	MANTA	15 DE ABRIL	48
1302	MANABI	MANTA	24 DE MAYO	1
1303	MANABI	MANTA	LOS ESTEROS	302
626	ESMERALDAS	ESMERALDAS	HERMANOS CA	5
627	ESMERALDAS	ESMERALDAS	SAN PABLO	22
624	ESMERALDAS	ESMERALDAS	EL ARENAL	73
625	ESMERALDAS	ESMERALDAS	SAN VICENTE D	5
623	ESMERALDAS	ESMERALDAS	SAN JOSE COTT	59
520	EL ORO	PASAJE	GALAYACU	13
621	ESMERALDAS	ESMERALDAS	CENTRO DE SAL	64
523	EL ORO	PASAJE	UZHCURRUMI	1
522	EL ORO	PASAJE	TRES CERRITOS	65
1575	PASTAZA	MERA	SHELL	2
1587	PASTAZA	ARAJUNO	CURARAY	0
2034	ORELLANA	LORETO	24 DE MAYO (DI	1
1301	MANABI	MANTA	SAN LORENZO	96
2037	ORELLANA	ORELLANA	TARACOA	2
2802	NAPO	TENA	MUYUNA	2
1046	LOJA	GONZANAMA	GONZANAMA	1
2798	SUCUMBIOS	SHUSHUFINDI	CS URBANO SHI	17
2069	SANTO DOMINI	SANTO DOMINI	PARAISO	85
2063	SANTO DOMINI	SANTO DOMINI	JUAN EULOGIO	11



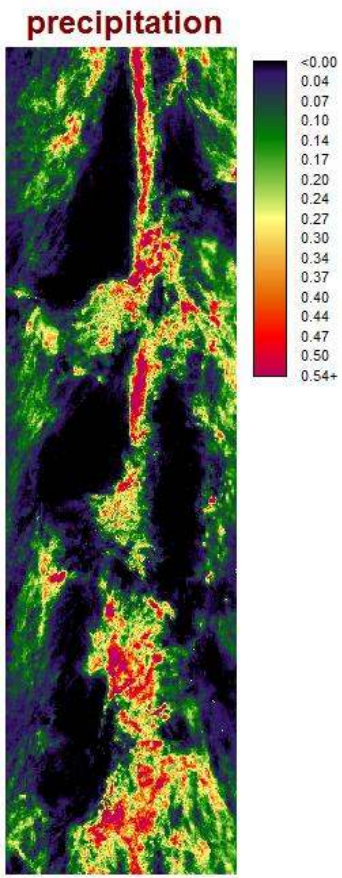
disaggregate



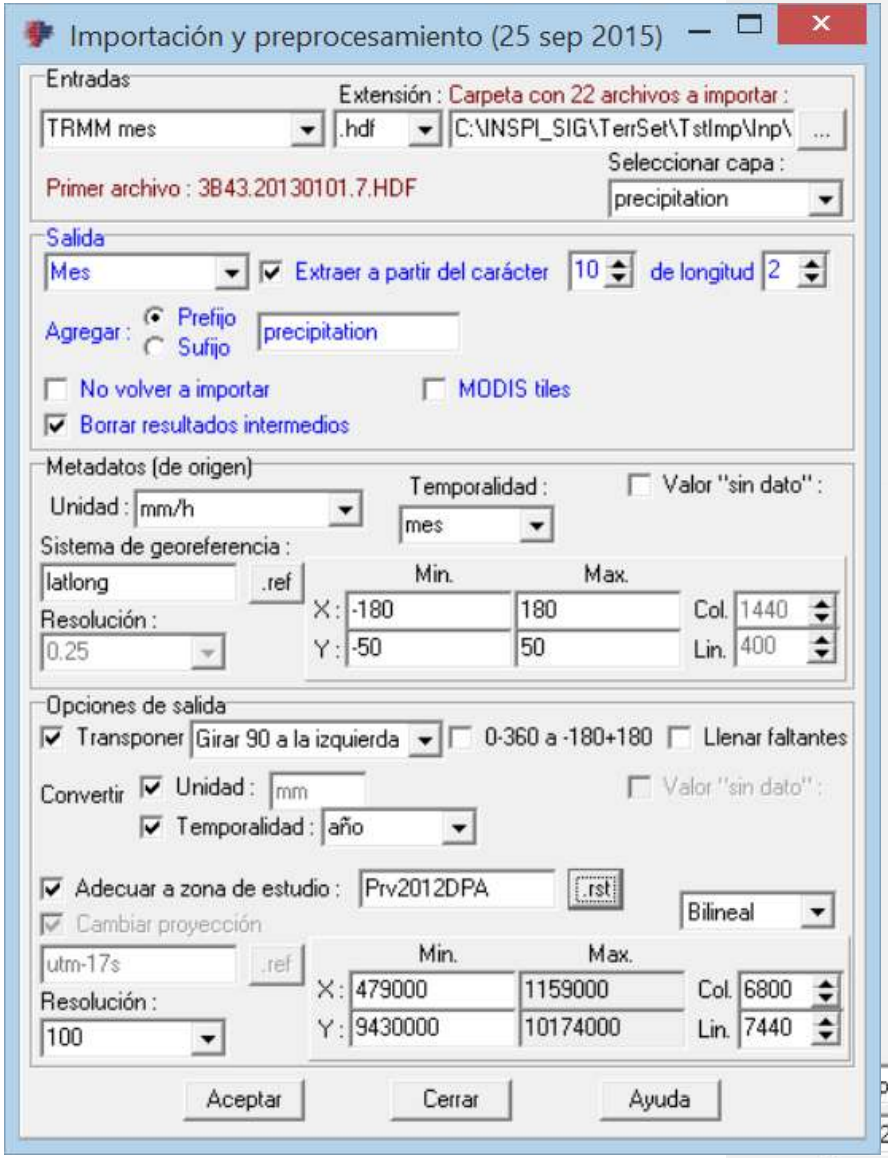
Automated geolocalization of cases

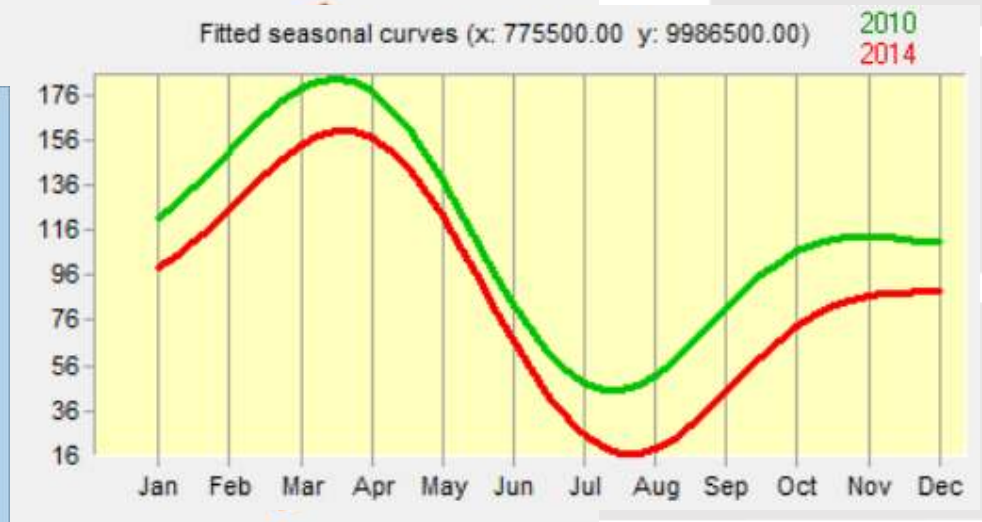


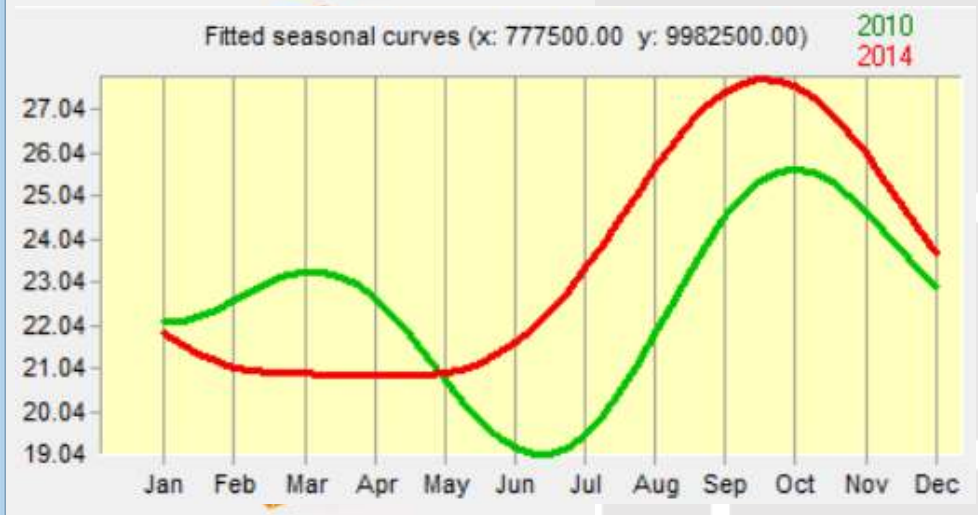
Satelite image source



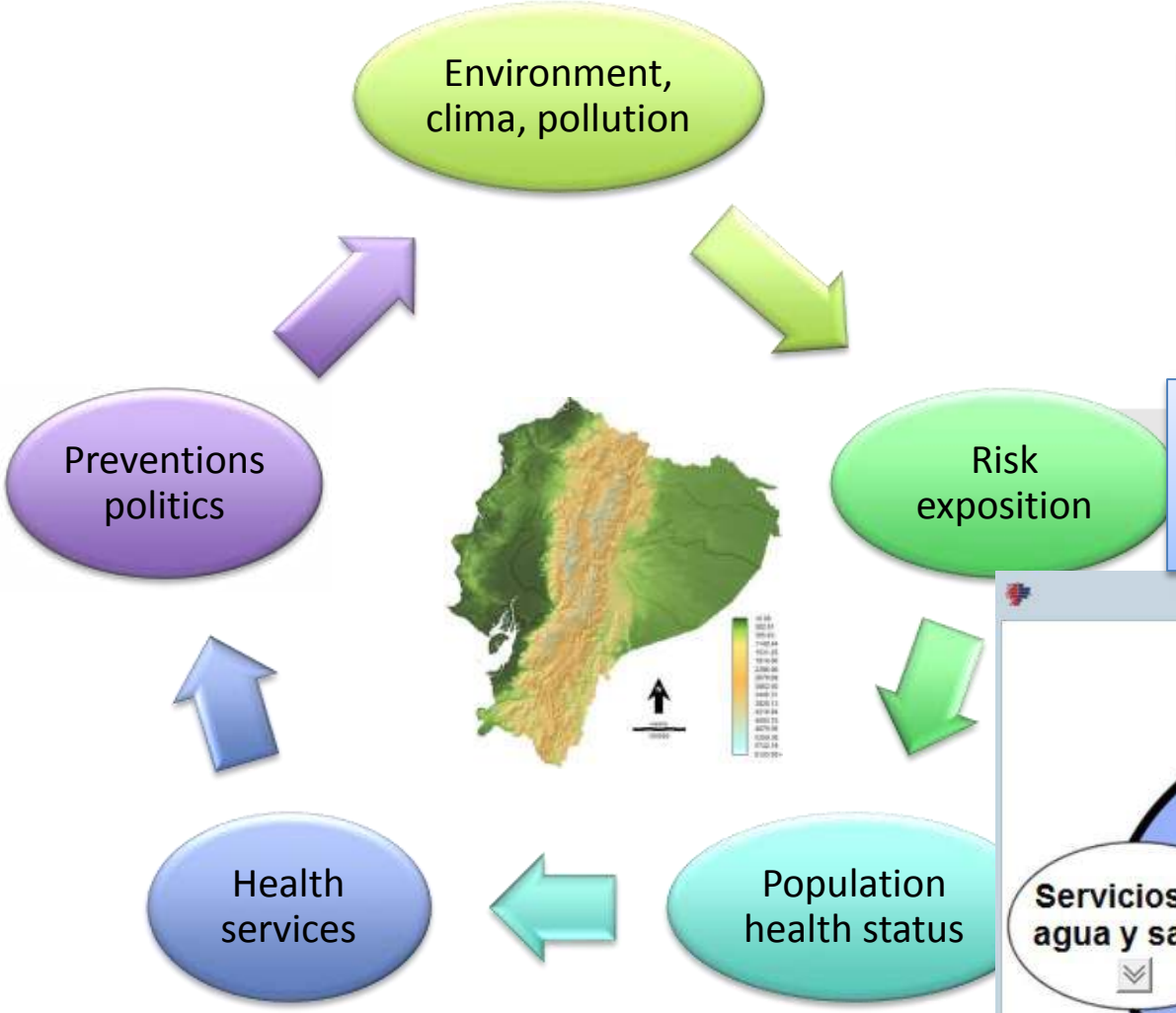
Satelite image preprocessing





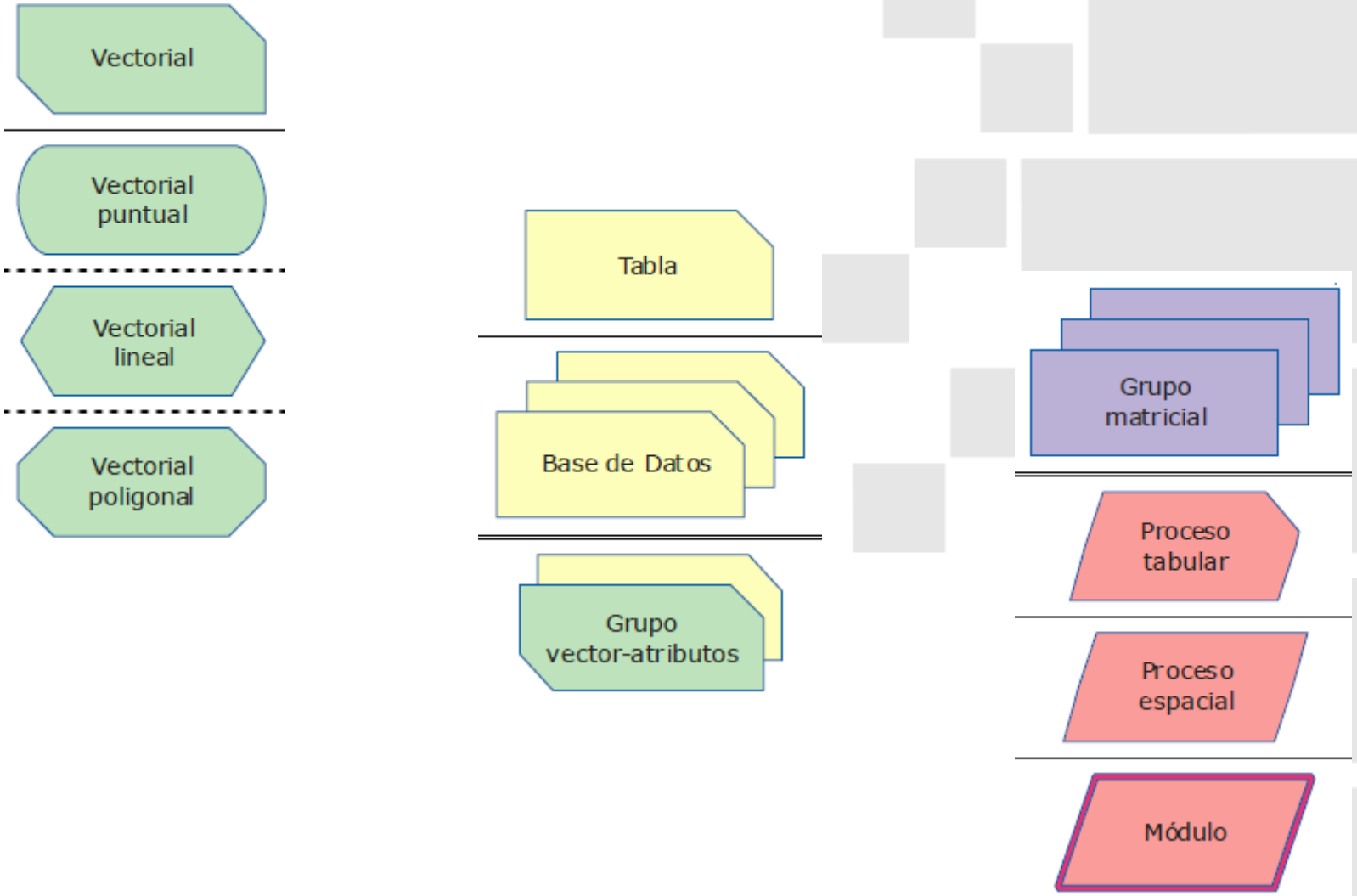


Logical scheme



Module interface implemented for water related diseases

Geomatic symbology

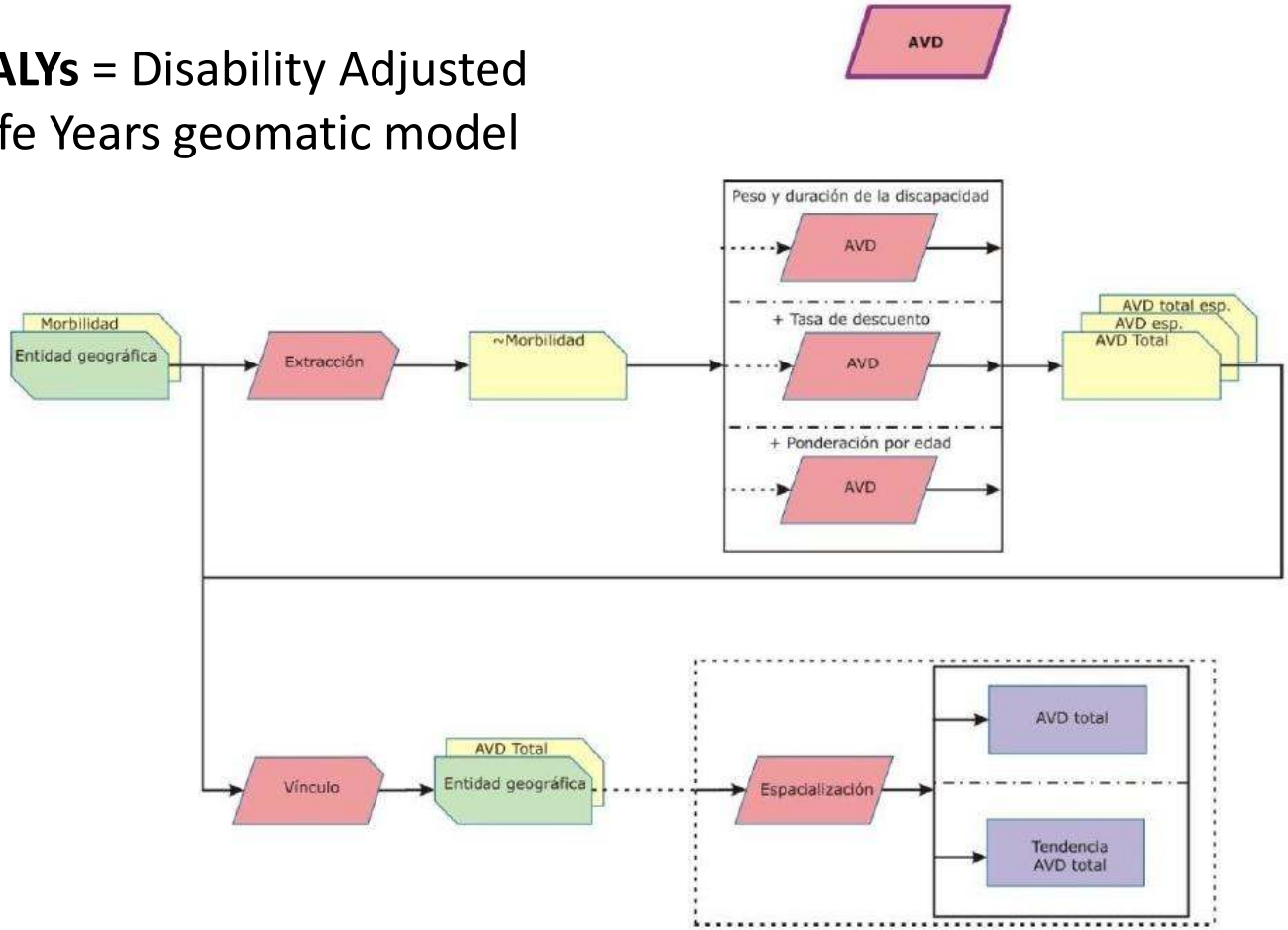


Indicators

DALYs = Disability Adjusted Life Years spatial equation

$$b_z^* = \sum_{i=1}^{I} c_{ij}\, w_j \left(\frac{KCe^{ra}}{(r+\beta)^2} \left(e^{-(r+\beta)(L+a)} \left[-(r+\beta)(L+a) - 1 \right] - e^{-(r+\beta)a} \left[-(r+\beta)a - 1 \right] \right) \right) + \left(\frac{1-K}{r} \left(1 - e^{-rL} \right) \right)$$

DALYs = Disability Adjusted Life Years geomatic model



Health indicators

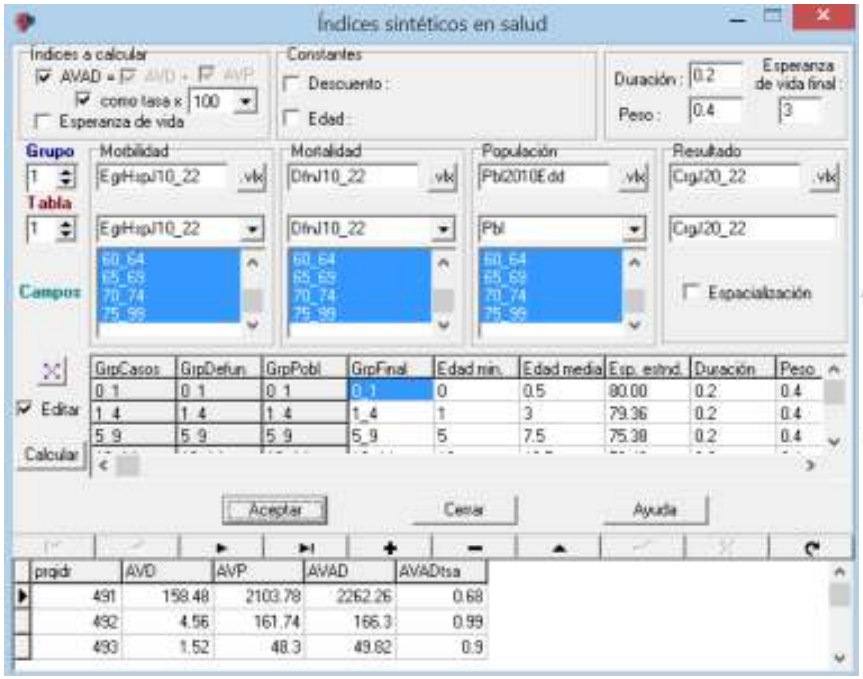
Based on data of morbility (disease cases), mortality (deaths) and population, **frequency measures** allow to evaluate the health status of a population.

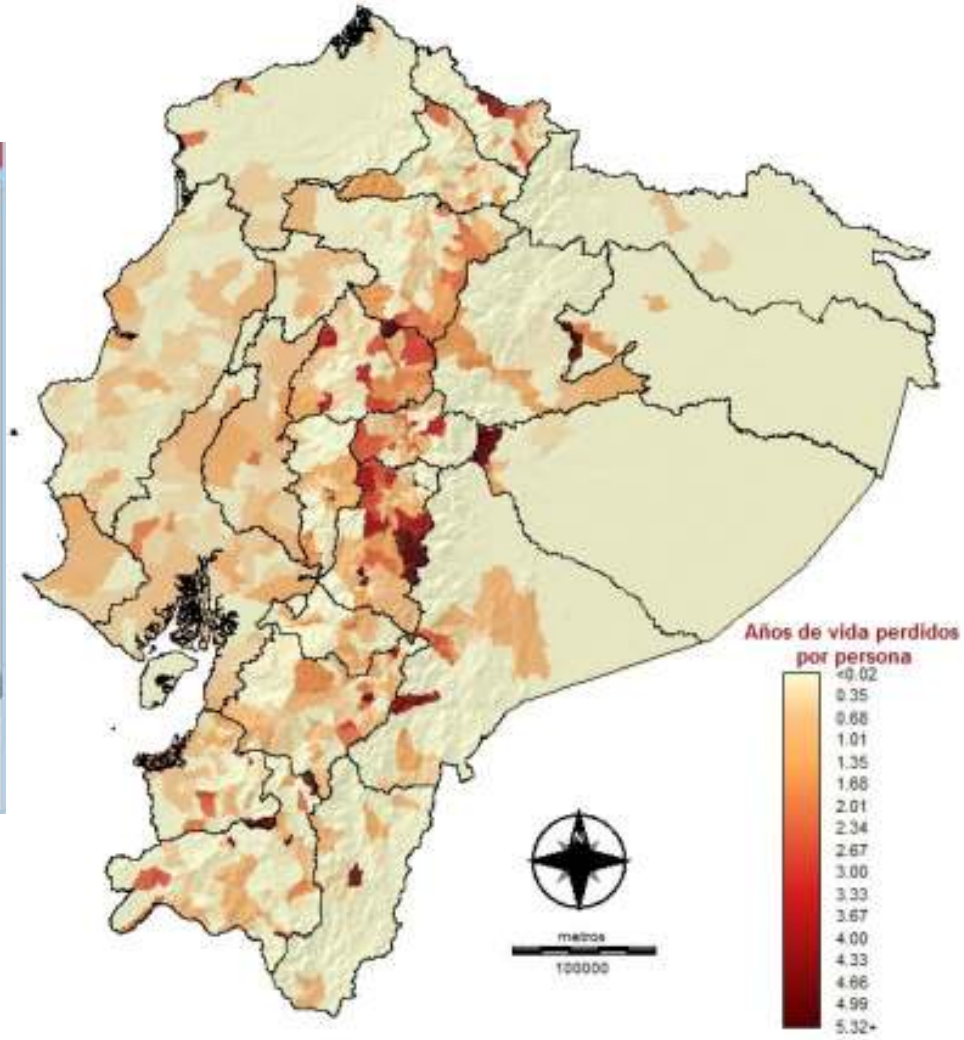
Health		
Cases	Fatality	Deaths
Cause proportion		Cause proportion
Cumulative incidence		Death probability
Instantaneous incidence		Mortality rate
Adjusted incidence		Ajusted mortlity rate
YLD >	DALY	< YLL < Esperanza de vida
	Population	

DALY = Disability-Adjusted Life Year = YLD + YLL
YLD = years lived with disability
YLL = years of life lost

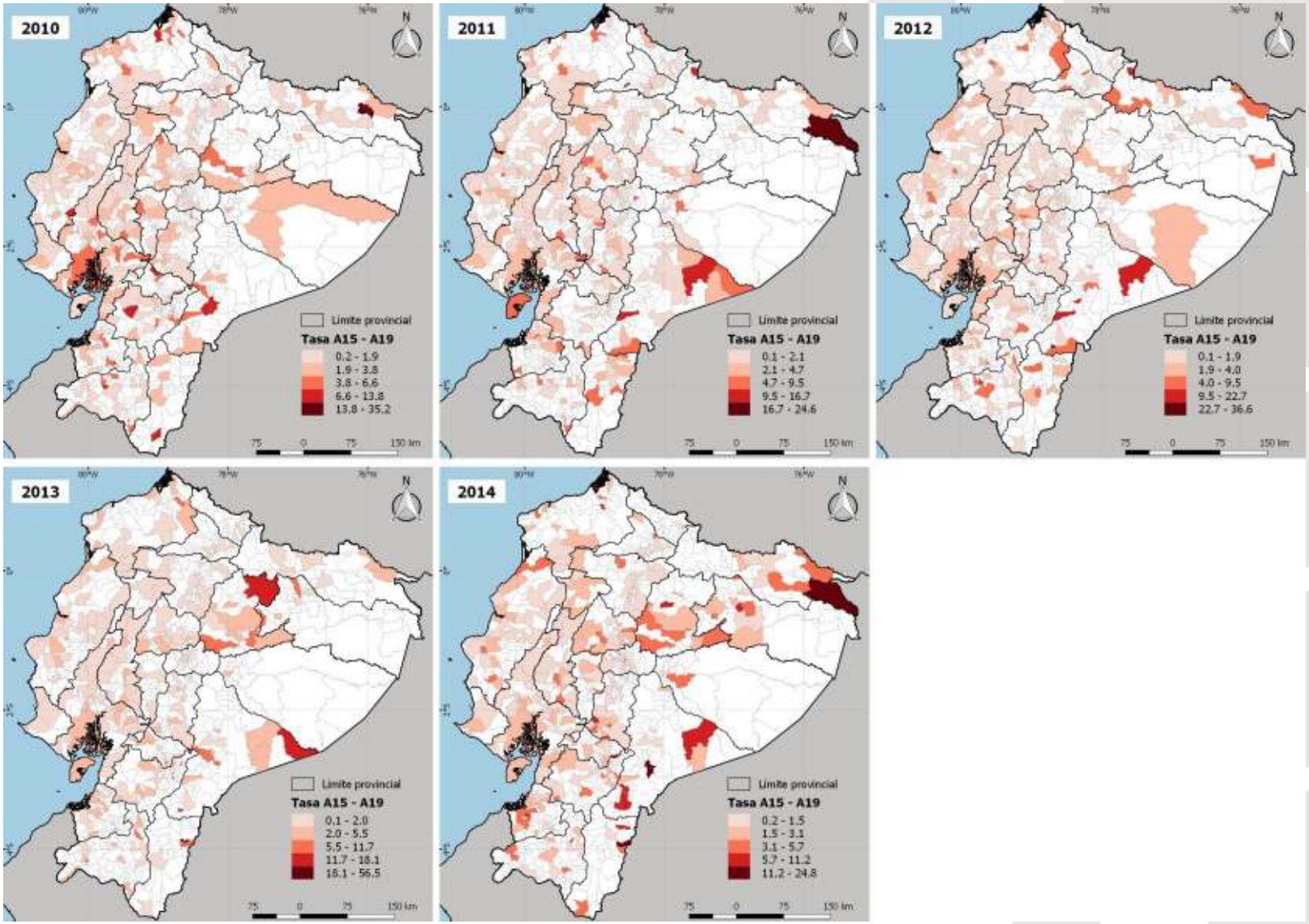
Burden rate for acute respiratory infections

DALY for J09 a J22
(influenza, neumonia, bronquitis)
in 2010





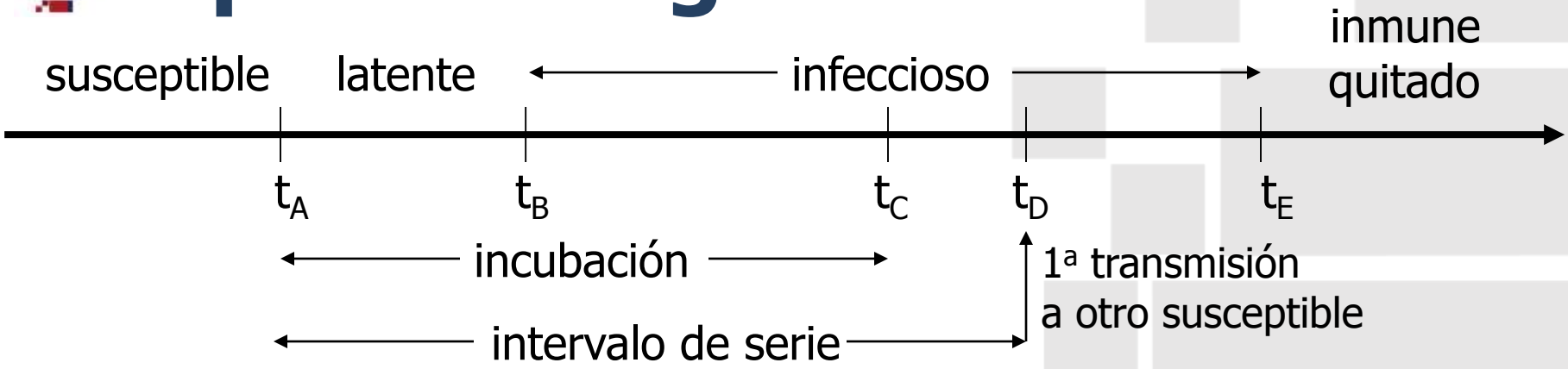
Incidence for tuberculosis

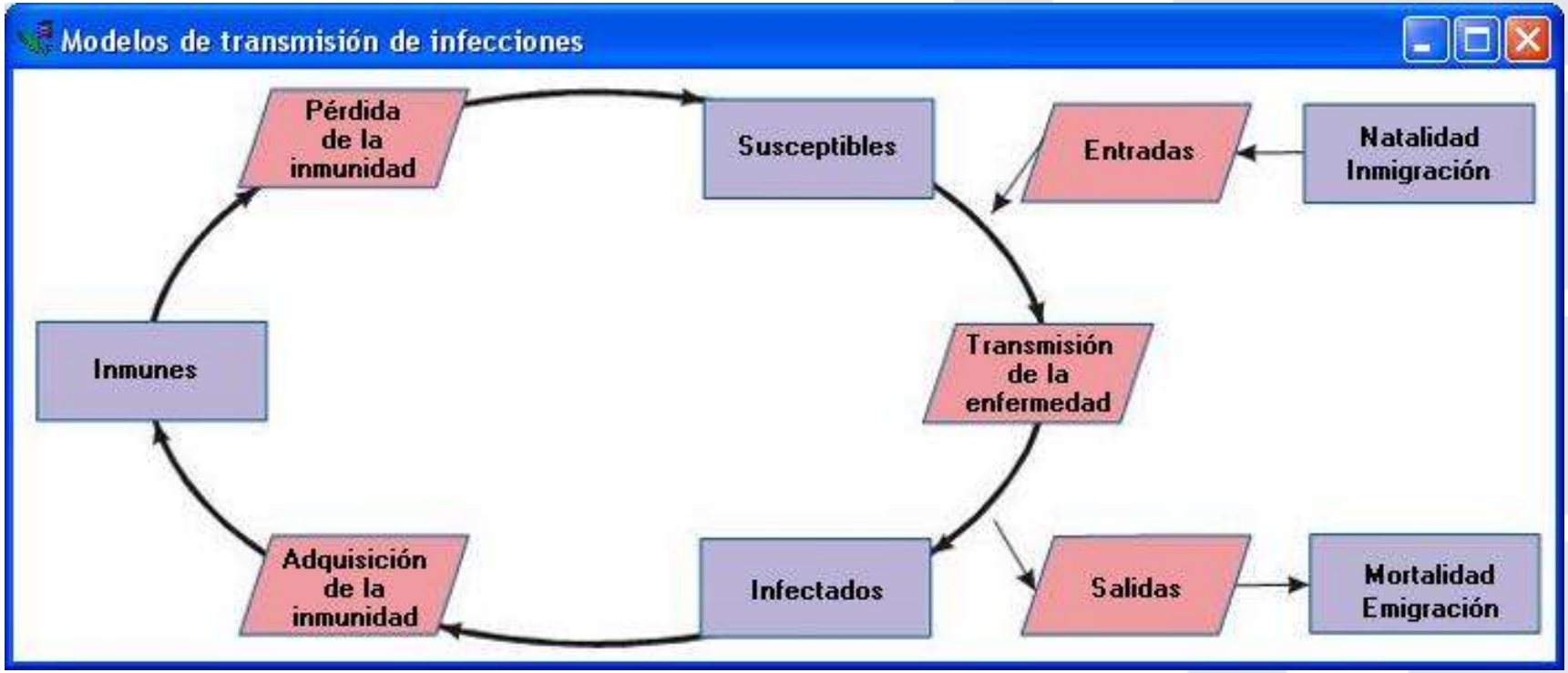


Prioritization methodology

- Under development
- Need to have a scientific-based criteria to focus on the most critical diseases for Ecuador according to time trend and differentiated in space location
- Proposal : develop a method based on disease burden cubes, extracting monotonic trend (Mann-Kendall) or linear trend (ordinary least squares regression)

Epidemiologic model





Other models to apply or implement

- **Outbreak** analysis
  - endemic **channel**
  - epidemiologic graph
- **Regression** (or multi-regression)
  - linear
  - logistic
  - Poisson (for diseases with low frecuencies)
- **Propagation** models for communicable diseases
  - deterministic (no aleatoriedad) : continuous time (diffential equation of logistic growth), or discrete time
  - estocastic : continuous time (Markov chain model), or discrete time (Greenwood and Reed-Frost model)
- **Survival** analysis models
  - Parametric (exponential, Weibull, Log-normal, Gamma)
  - Non parametric (life table, Kaplan-Meier estimator)
  - Proportional risks (Cox)

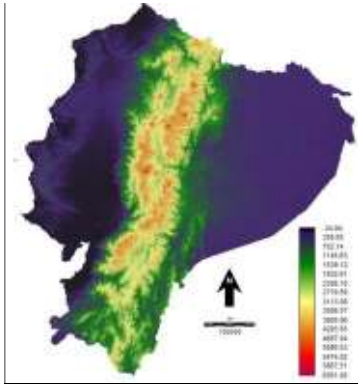
SOME EXAMPLES OF RESULTS

Geodatabase

Spatial resolution: 1 ha, 1 km^2

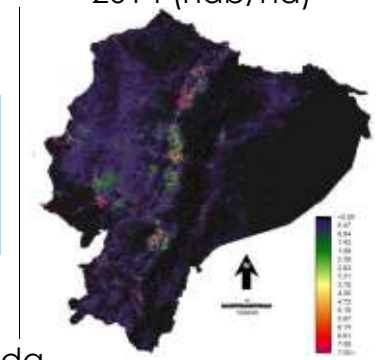
BÁSIC GEODATA

ELEVATION
SRTM - Shuttle Radar Topography Mission)

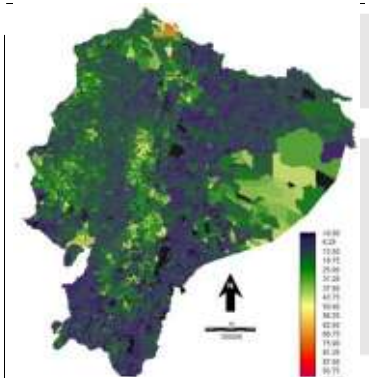


SOCIOECONOMIC LAYERS
(INEC 2010)

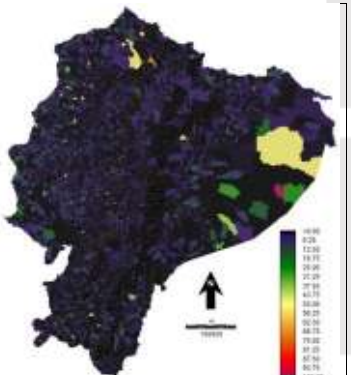
Densidad población 2014 (hab/ha)



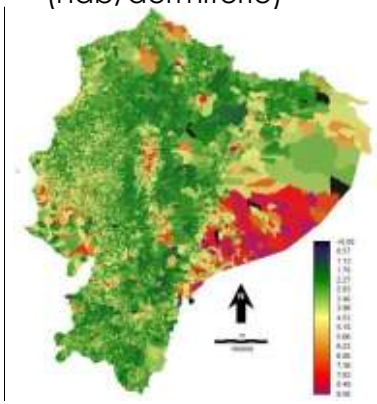
Analfabetismo (%)



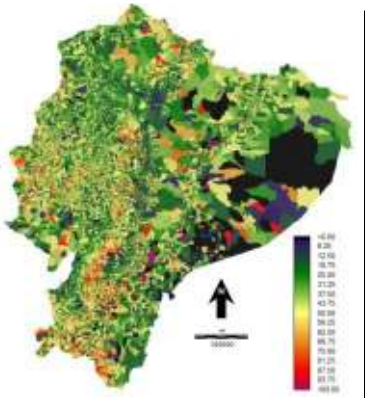
Desempleo (%)



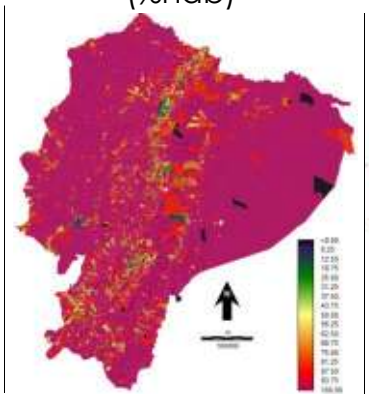
Hacinamiento (hab/dormitorio)



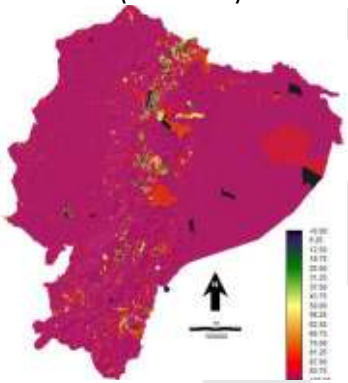
% de hab. en vivienda en mal estado



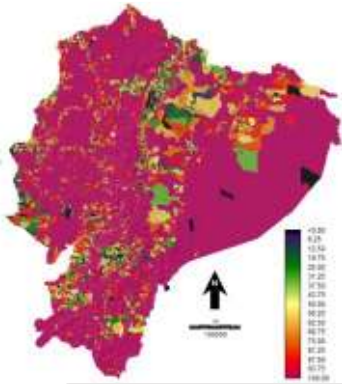
Sin acceso a agua (%hab)



Sin alcantarillado (% hab.)

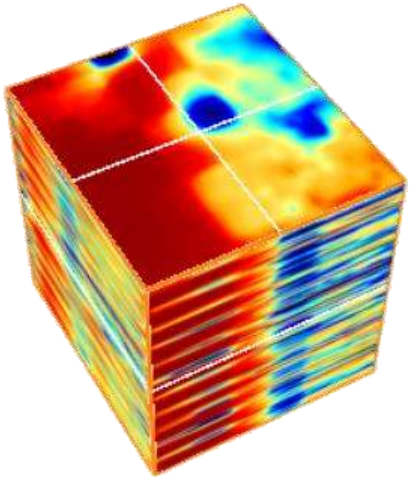


Sin recolecta de basura (% hab.)



Precipitation time series

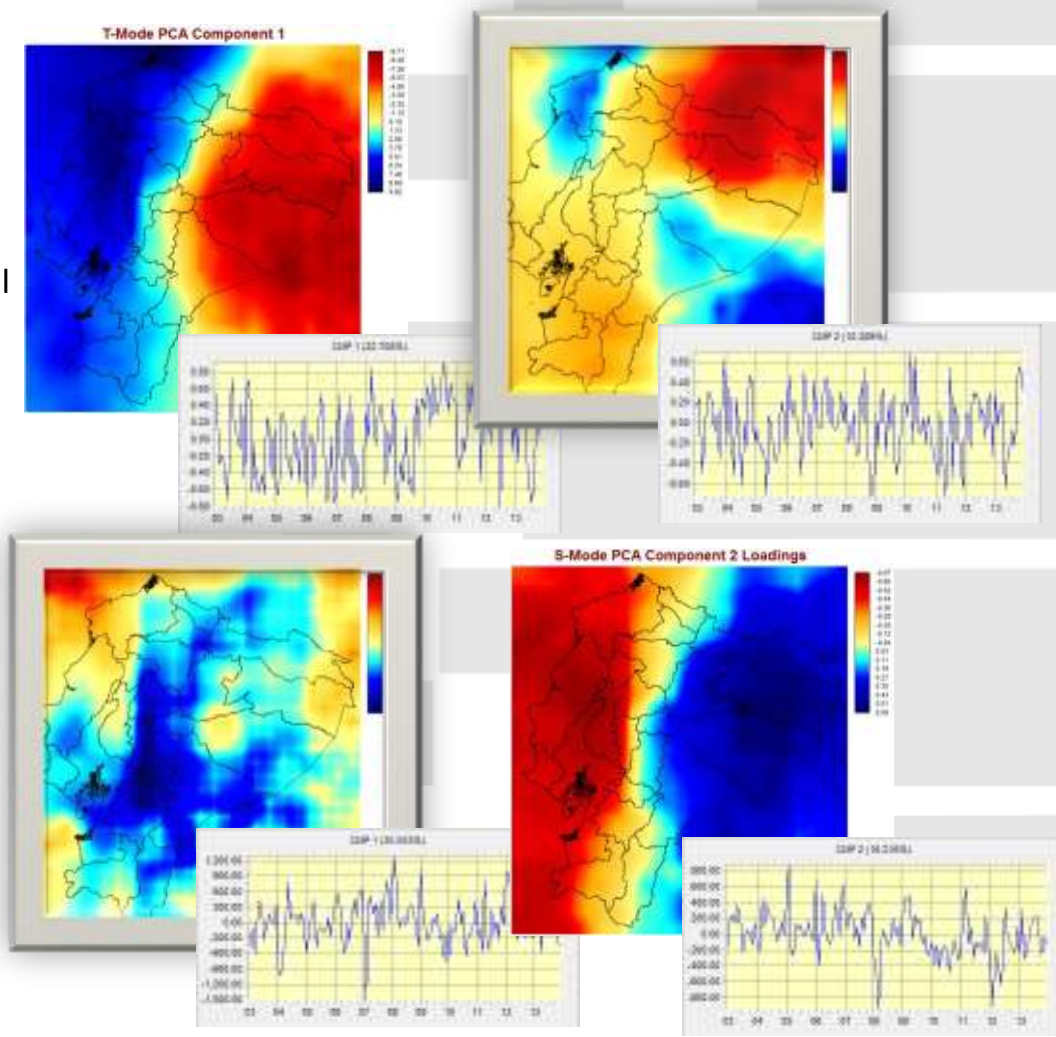
Precipitación mensual (*TRMM - Tropical Rainfall Measuring Mission*) 2003-2015



Modo **T**emporal

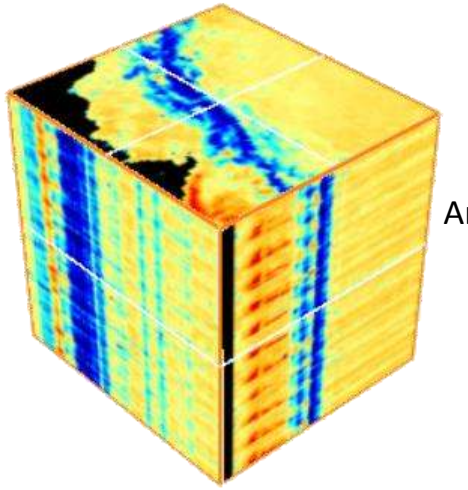
Anomalía + Análisis en Componentes Principales (*PCA - Principal Components Analysis*)

Modo e**S**pacial



Temperature time series

Temperatura mensual
(*LST - Land Surface Temperature, MODIS*)
2003-2015



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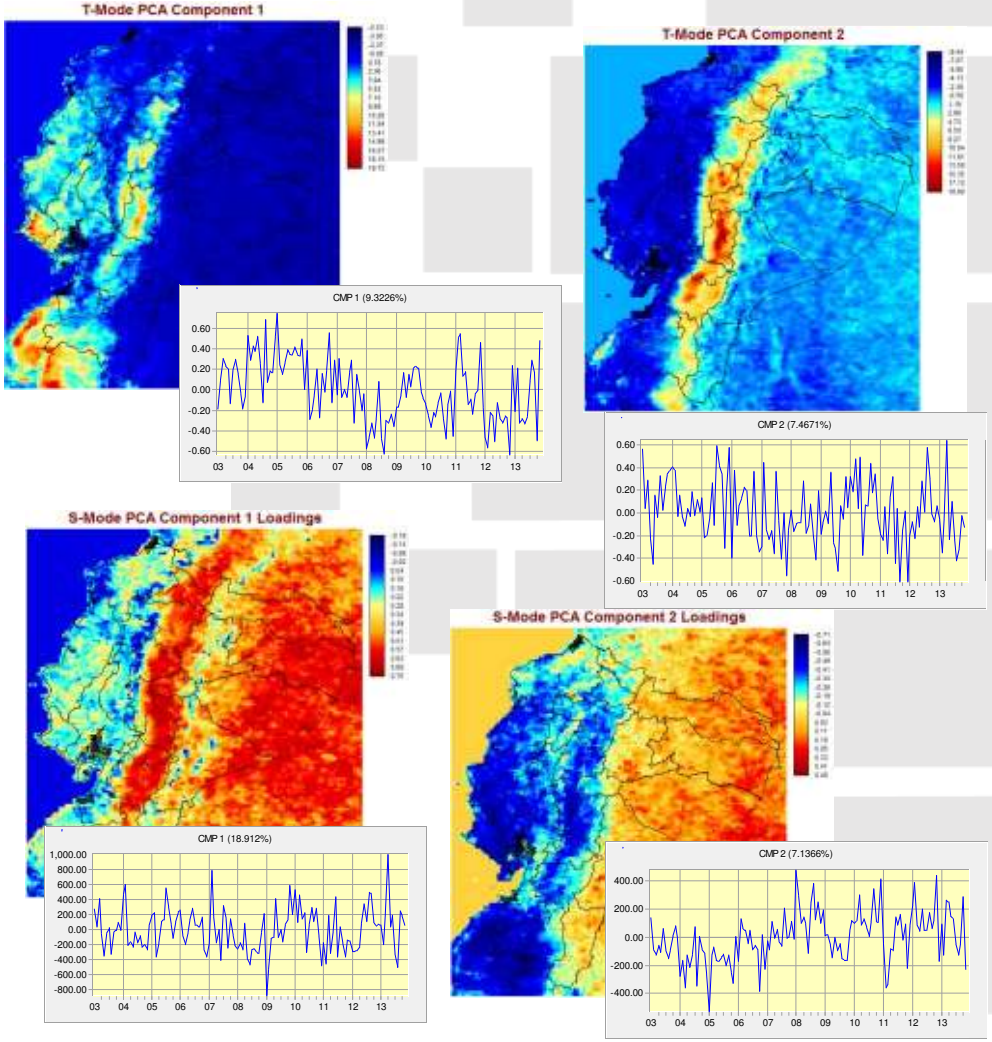
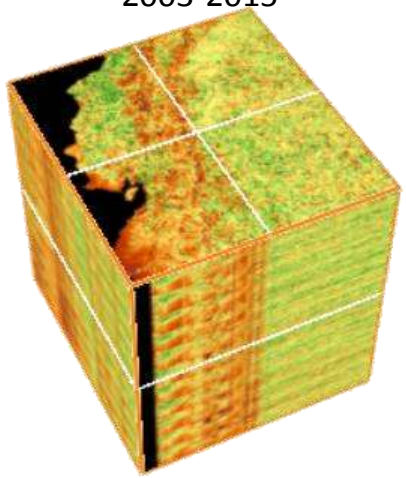


Vegetation time series

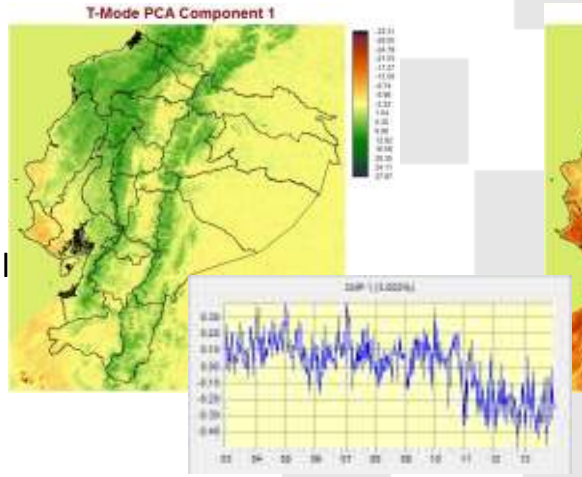
Índice de vegetación mejorado 8-días (*EVI - Enhanced Vegetation Index, MODIS*)
2003-2015

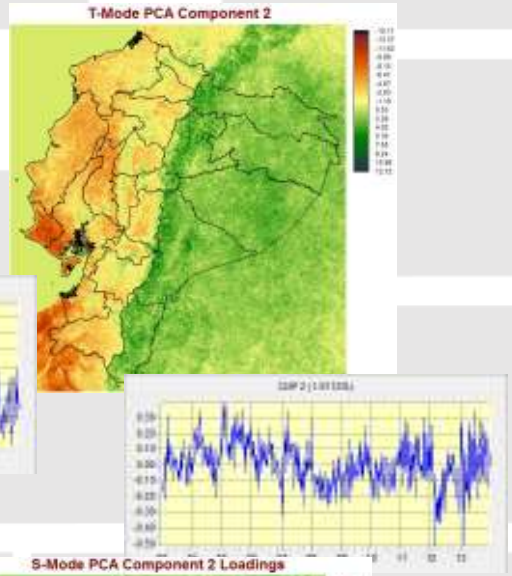


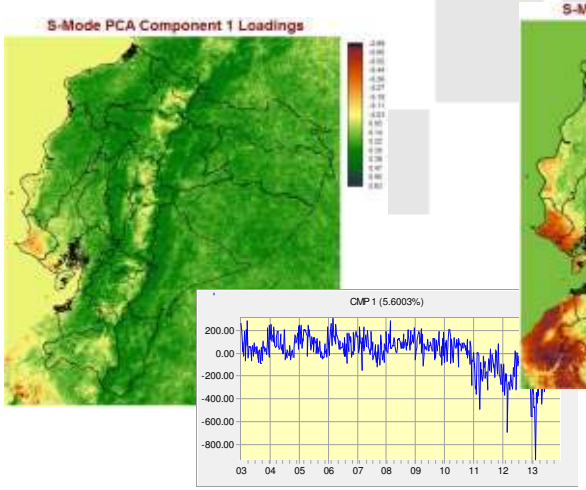
Modo **T**emporal

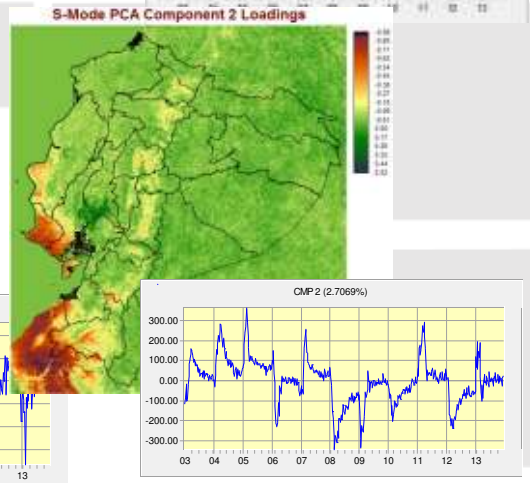
Anomalía +
Análisis en Componentes Principales (*PCA - Principal Components Analysis*)

Modo e**S**pacial









Multicriteria evaluation for malaria

Steps for multicriteria evaluation in GIS

Obtener el mapa de cada factor (importación, distancia,…)

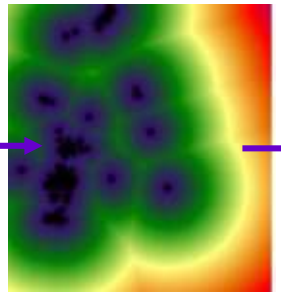
Re-escalar los factores del valor menor a más favorable para la presencia del vector (operación Fuzzy)

Establecer el peso de cada factor (proceso analítico jerárquico AHP)

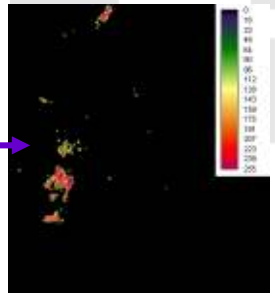
Combinar los factores utilizando un criterio de decisión (valor mínimo o compensación entre factores)

Para facilitar la toma de decisión según límites administrativos, se puede asignar a cada distrito el valor medio

Distance



Fuzzy



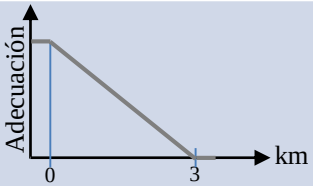
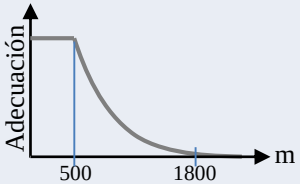
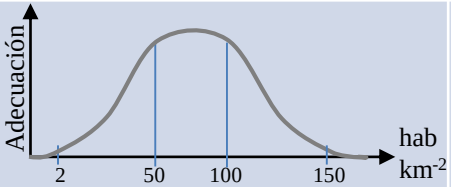
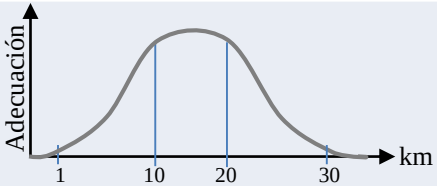
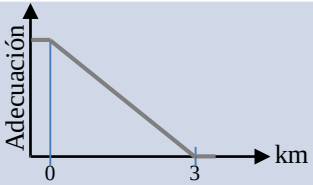
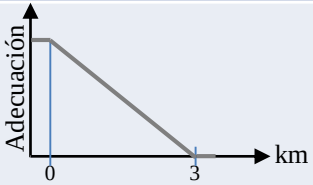
Compensación entre factores

Triángulo de la decisión

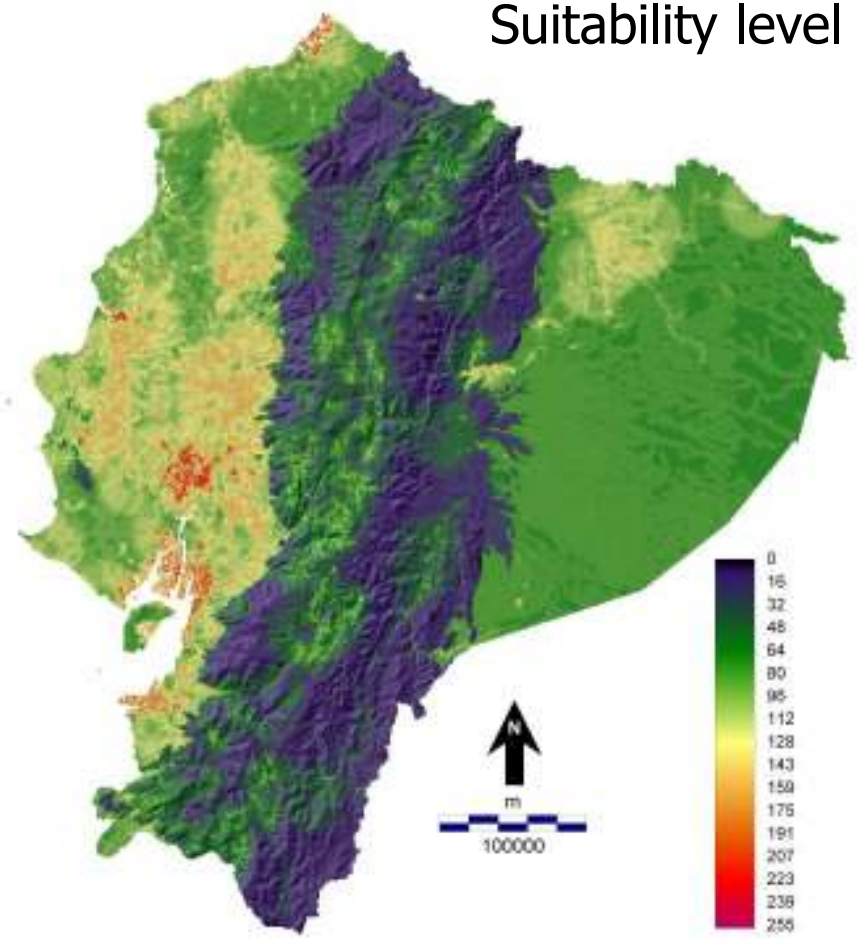
Riesgo en la decisión minimizado

Opción más permisible

Suitability for *Anopheles*

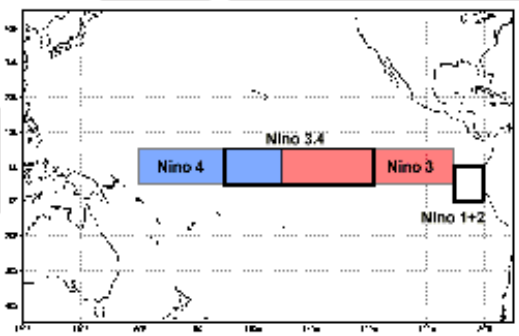
Factor	Unidad	Rango favorable para *Anopheles*	Peso
Distancia a zonas húmedas	m (km)		36%
Altitud	m (m.s.n.m.)		26%
Densidad de población	Personas por superficie		18%
Distancia a zonas pobladas	m (km)		9%
Distancia a vías terrestres	m (km)		6%
Distancia a ríos	m (km)		5%

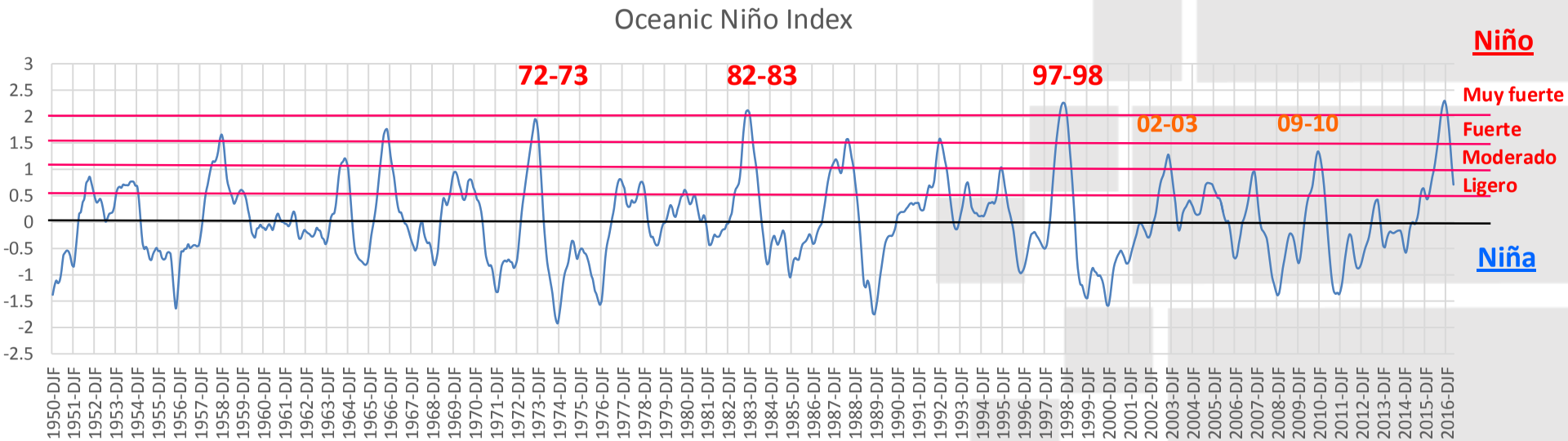
Suitability level



Referencia : Fuller D.O., A. Troyo, T.O. Alimi, J.C. Beier (2014). Participatory risk mapping of malaria vector exposure in northern South America using environmental and population data. Applied Geography 48 (2014) 1-7

El Niño 2015-2016





ONI = 3-month running means of SST anomalies in the Niño 3.4 region [5N-5S, 120-170W]

http://www.cpc.noaa.gov/data/indices/oni.ascii.txt

Suitability modeling for vector or virus

- Model for Ene-Jun 2015
- Simulation with "El Niño" 1998

Elevation

Slope

Precipitation

Temperature

Vegetation

Anomalías 2015 con 2010-2014

PCA
T-mode
S-mode

Population

Illiteracy

Unemployment

Overcrowding

Housing

Water and garbage services

Condition (floor, wall, roof)

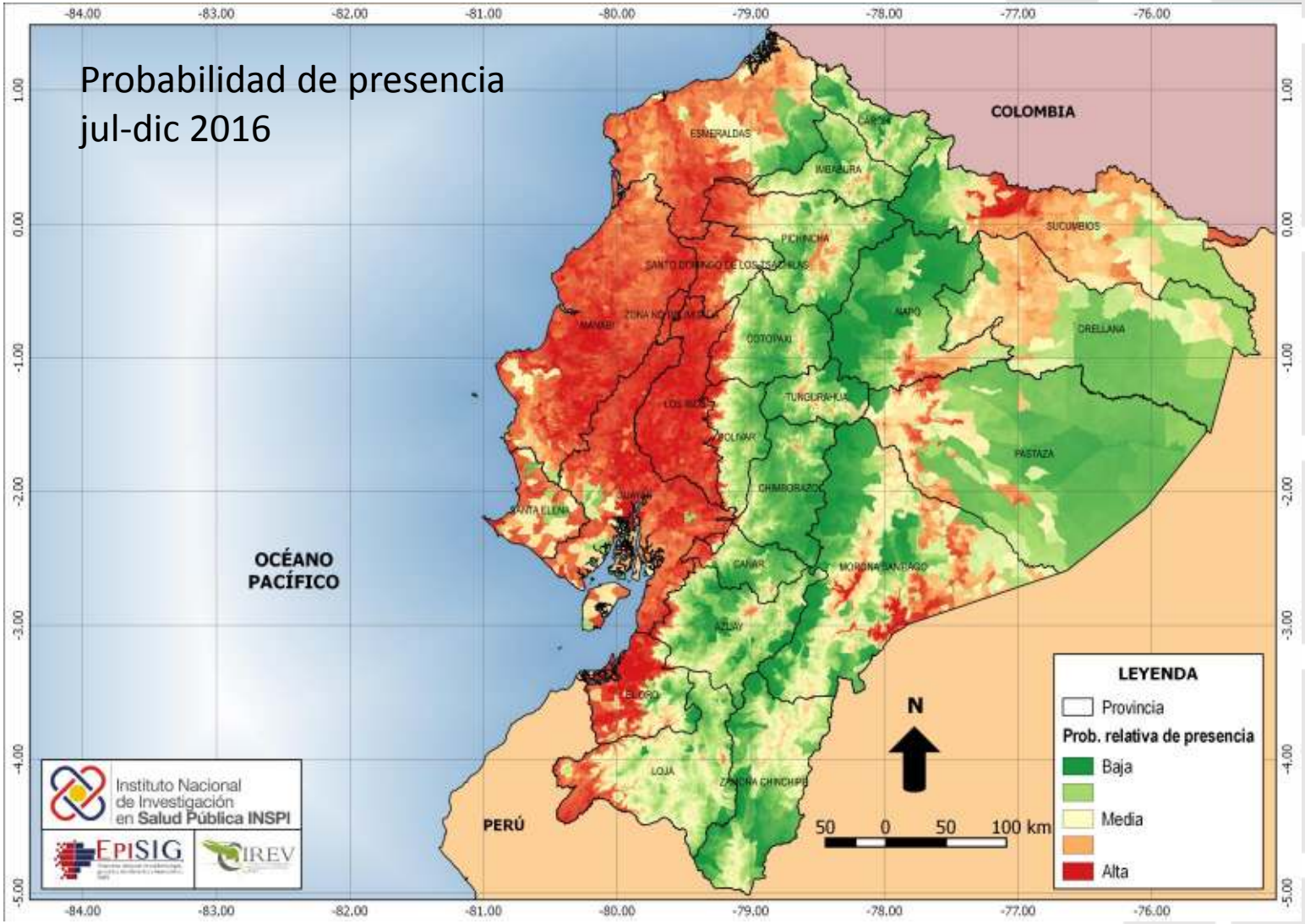
Presence of the studied specie (Aedes, virus)

Maxent

Computer learning technic using statistics, maximum entropy and bayesian methods, in order to estimate probability distributions of maximum entropy subject to restrictions given by environmental and social layers.

Relative probability of presence

Dengue-chikungunya simulation



Application of climate change models in GIS

MAGICC
Model for the Assessment of Greenhouse-gas Induce Climate Change

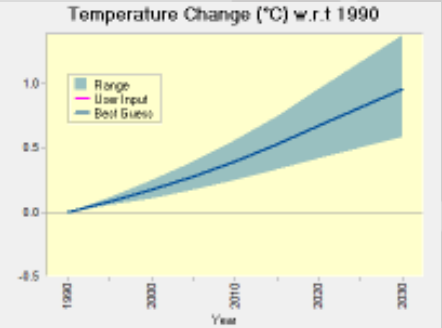
Modelos de Ciclo de Gas

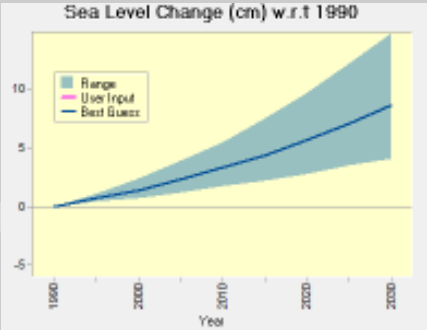
A2GIM

		Global	Regional
		1	2
Énfasis en la riqueza humana	A		X
Tecnologías limpias Sostenibilidad social	B		

GIM -IMAGE => Health Inst. Países Bajos

Salida de temperatura media global y nivel del mar



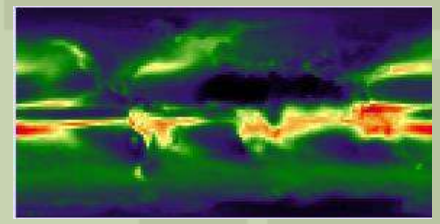


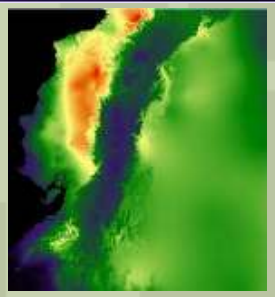
Biblioteca de climatología base (1981-2000)

Biblioteca de datos de AOGSM

Algoritmo de regionalización

Mapa de temperatura y precipitación

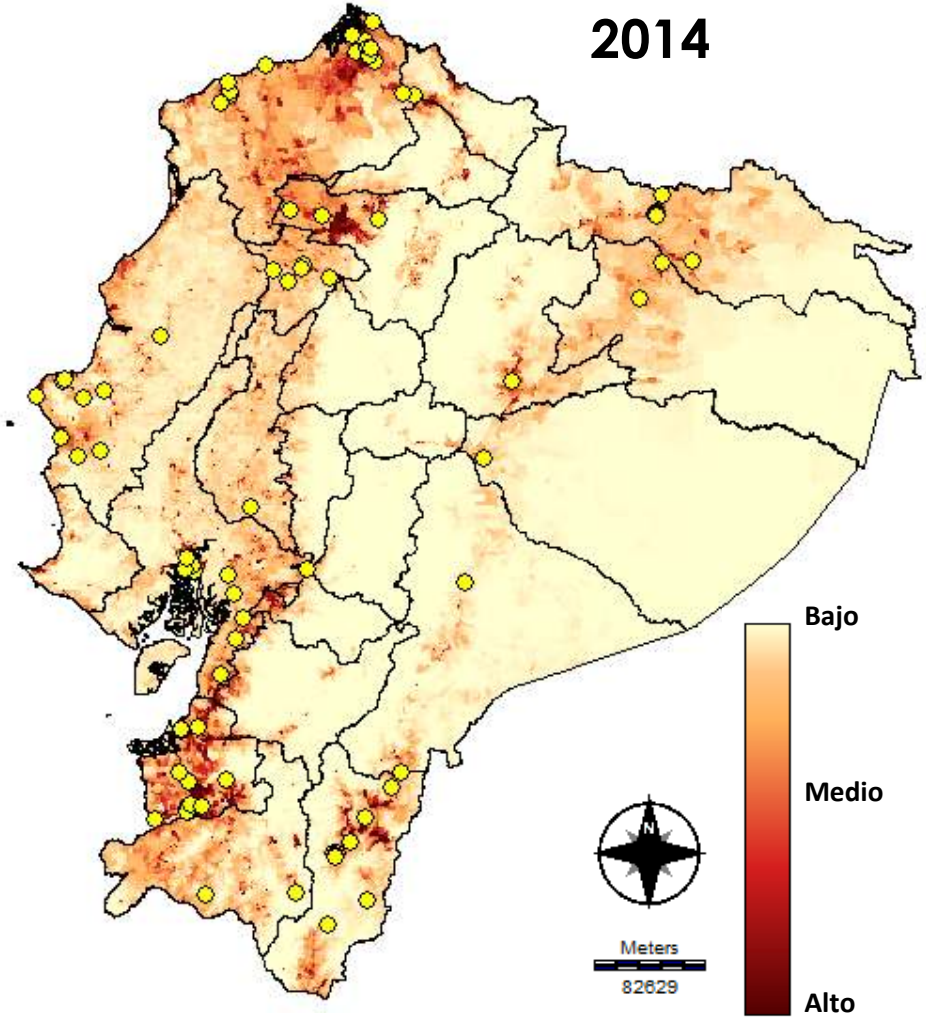


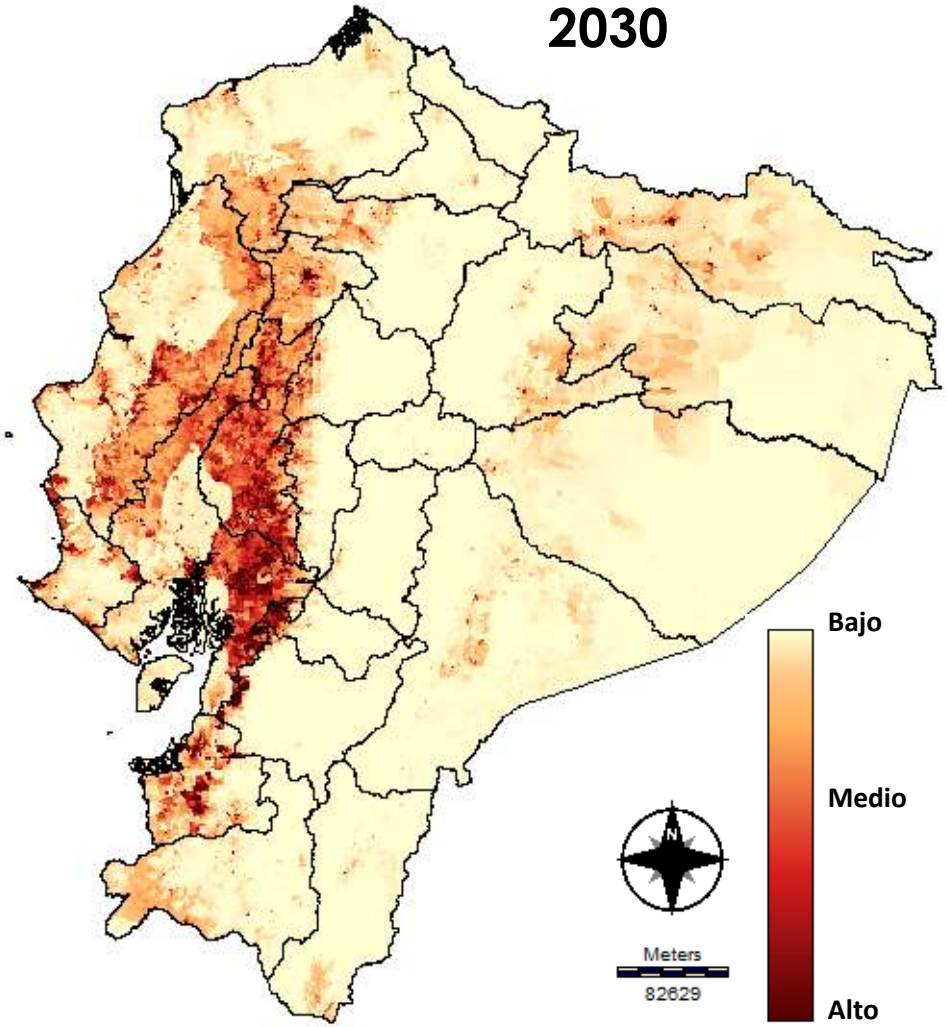


Downscale

SCENGEN
Generate Climate Scenarios

Climate chante simulación to 2030





Presencia registrada de *Aedes aegypti*

For more information

- E-mails

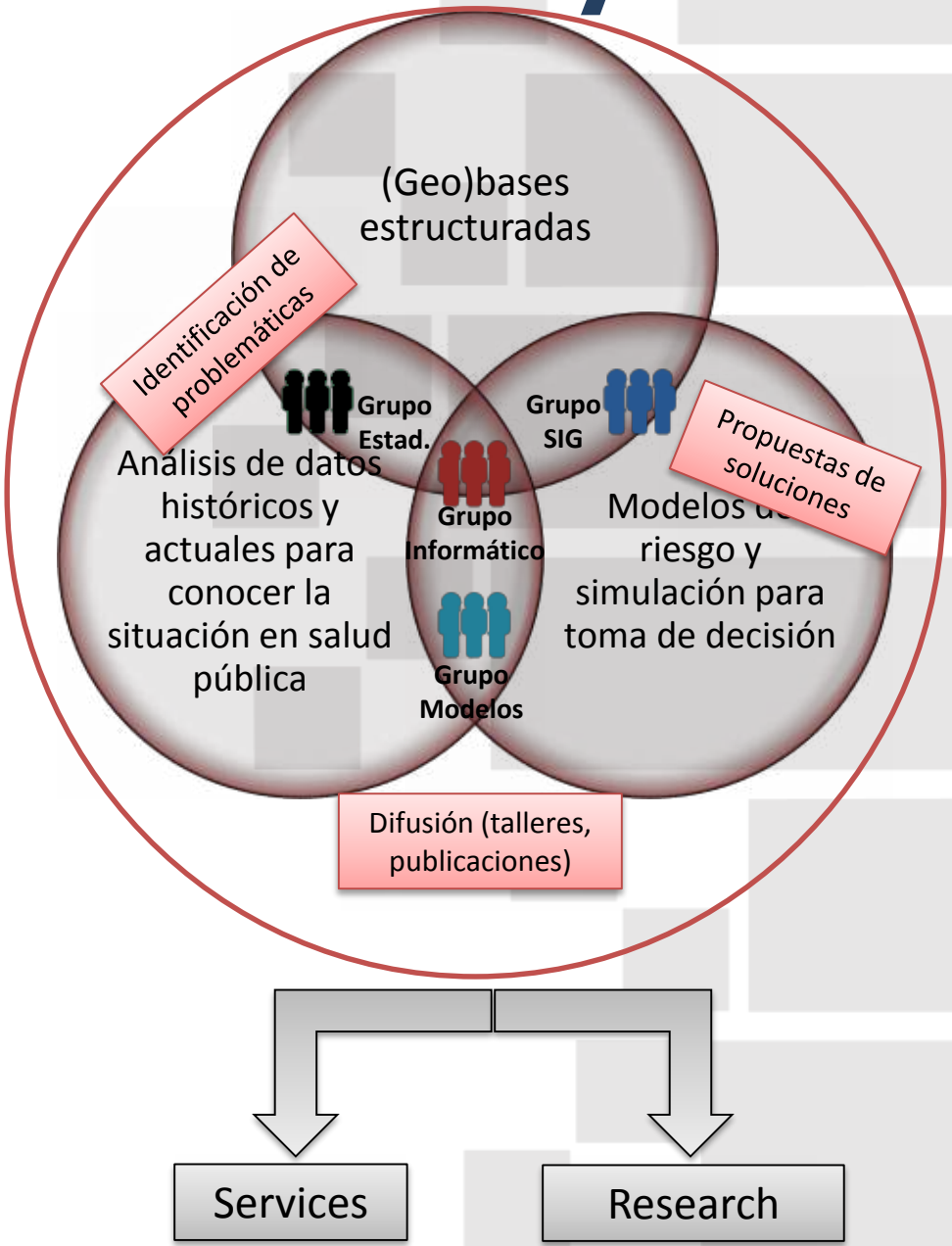
  episig.inspi@gmail.com, episig@inspi.gob.ec
- Web site of EpiSIG

  http://www.investigacionsalud.gob.ec/webs/episig/
  – Request form online

INSPI-EpiSIG core utility

The EpiSIG core utility is in charge of:

Compiling, structuring, **analyzing, modeling** and presenting results related to public, particularly to provide information and tolos to the health authorities (MSP), in order to support decision taking.



THE END...

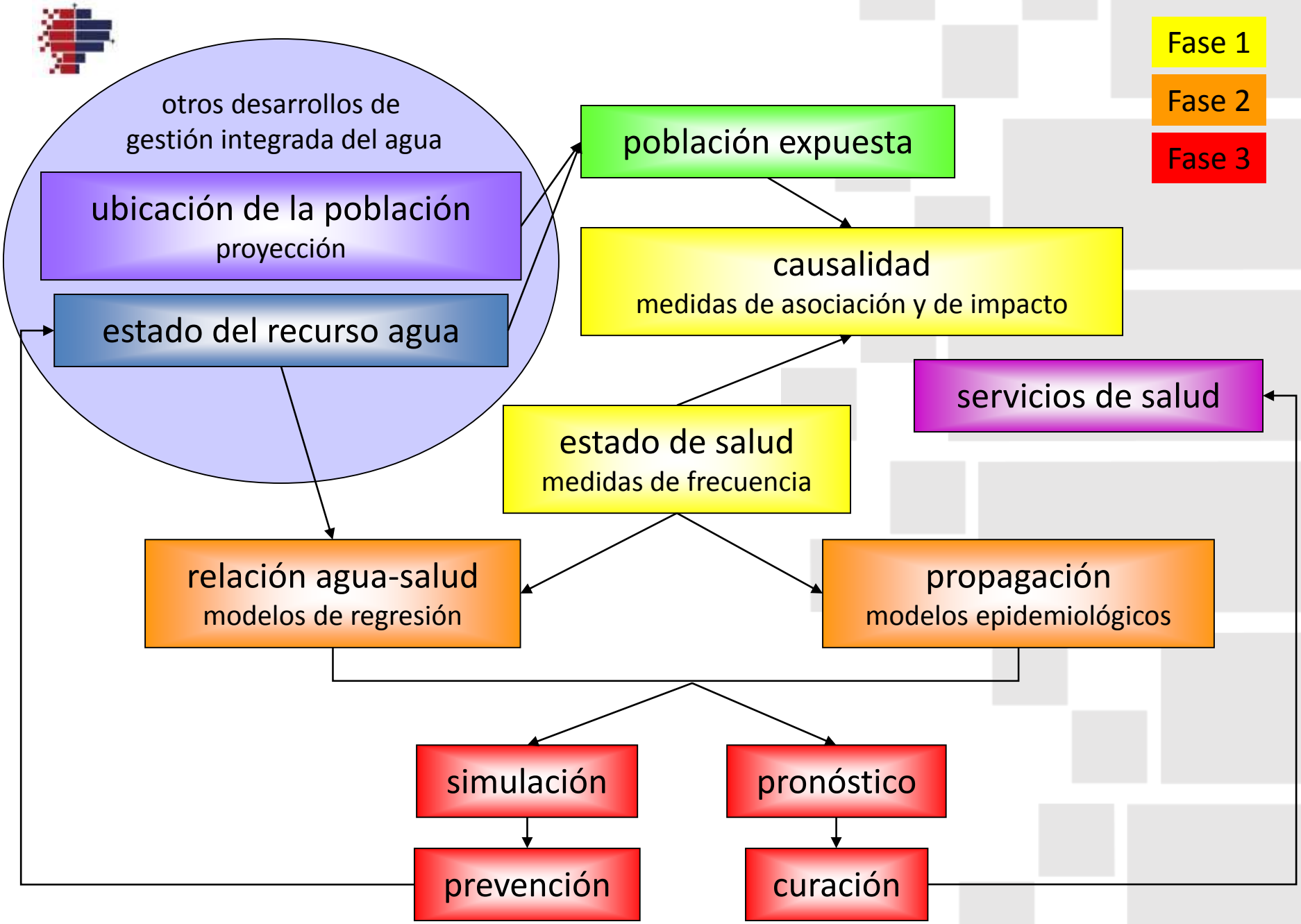
Abstract

- Ecuador is passing through an epidemiologic transition where both communicable diseases are still high and chronical illness due to new ways of living, less traditional, are becoming the principal issues. There is some databases at national level that can help the Ministry of Health to orient its decisions. But there is no easily available and efficient spatio-temporal tool that can help to determine what, when and where the public policies should focus.
- The purpose of this research is to develop an integrated GIS-based system for prioritization of health events in space and time. The first step presented here is how to articulate the conceptual framework necessary for this development. An important concept used to implement the first elements of this framework is the disease burden, spatially calculated as rate.
- Next steps will be dedicated to the modelling of the most important health issues identified in Ecuador.

Disponibilidad de imágenes

	Precipitación						Temperatura	Evapotransp.	Indice veg.
	TRMM		GPM	CMORPH	PERSIANN		MODIS 11C3	MODIS 16	MODIS 13Q1
	mes	día	mes	30 min	3 h	6 h	mes	mes	8 días
Formato	.hdf	.bin	.hdf5	.	.bin	.bin	.hdf	.hdf	.hdf
X mn→mx Y mn→mx	-180°→180° -50°→50°	0°→360° -50°→50°	-180°→180° -90°→90°	0°→360° -60°→60°	0°→360° -60°→60°	0°→360° -50°→50°	-180°→180° -90°→90°	tiles 10º x 10º	tiles 10º x 10º
C R	1440 400	1440 400	3600 1800	4948 1649	1440 480	1440 400	7200 3600	1200 1200	4800 4800
Res.	0.25°	0.25°	0.1º	8 km	0.25°	0.25°	0.05º	1 km	250 m
Syst. ref.	Lat-Long	Lat-Long	Lat-Long	Lat-Long	Lat-Long	Lat-Long	Lat-Long	Modis Sin.	Modis Sin.
Unidad	mm/h	mm	mm/h	mm/h	mm	mm	LST (50x(ºC+273.15))	mm*10	VI*10000
Tipo de dato	Real*4 No swap	Real*4 (Single prec.) Swap	Real*4 No swap	Real*4 No swap	Real*4 Swap	Real*4 Swap	Int	Int	Int
Geoproceso	Girar izq.	Invertir líneas	Girar izq.	Invertir líneas	Invertir líneas	Invertir líneas		Concatenar	Concatenar
Flag	No	No	-9999.9	-999			0 → sin dato	32761 →32767	-3000→sin dato

Pathogen element	Risk factor	Pathogen reservoirs	Transmission vector	Grupos de enfermedades las más frecuentes
Persistencia en el ambiente				
Productos tóxicos Helmintos Protozoarios Virus Bacterias	Factores naturales Altitud Clima Precipitación Inundación Sequía Temperatura	Recursos hídricos de superficie - ríos - lagos subterráneas	Agua para → beber, cocinar, higiene, bañarse	Infecciones intestinales Infecciones intestinales debidas a protozoarios Helmintiasis Salmonelosis
			Gotitas (Aerosoles)	
	Factores antrópicos Aprovechamientos hídricos Sistemas de abastecimiento y de tratamiento de agua Descargas → domésticas, agropecuarias, industriales		Animales de medios húmedos	Enfermedades por intermediarios Paludismo Dengue


Fase 1
Fase 2
Fase 3
otros desarrollos de
gestión integrada del agua
ubicación de la población
proyección
estado del recurso agua
población expuesta
causalidad
medidas de asociación y de impacto
servicios de salud
estado de salud
medidas de frecuencia
relación agua-salud
modelos de regresión
propagación
modelos epidemiológicos
simulación
pronóstico
prevención
curación

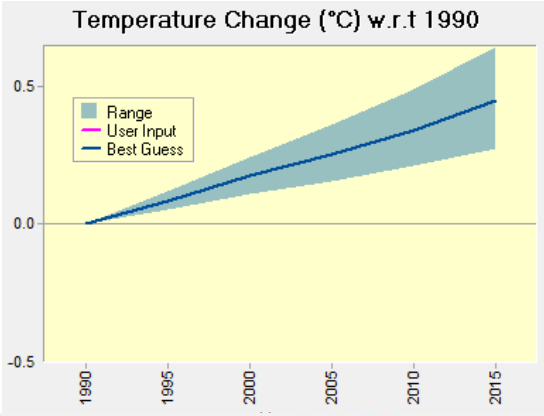
Asociación

- de diferencia (efecto absoluto) : riesgo atribuible
  - 0 → no asociación
  - < 0 → asociación negativa
  - > 0 → asociación positiva
- de razón (efecto relativo) :
  - 1 → no asociación
  - < 1 → asociación negativa, factor protector
  - > 1 → asociación positiva, factor de riesgo
  - razón de densidad de incidencia
  - razón de incidencia acumulada (razón de riesgos, riesgo relativo)
  - razón de prevalencias

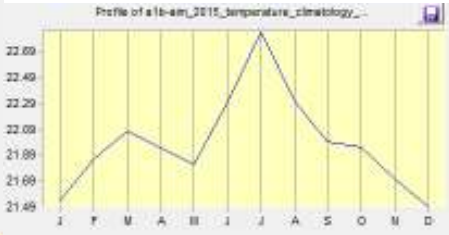
Impacto

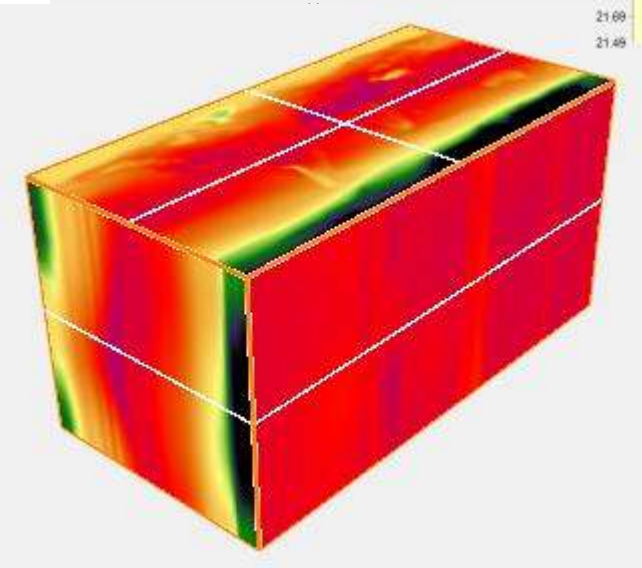
- Riesgo atribuible (fracción etiológica)
- Fracción prevenible

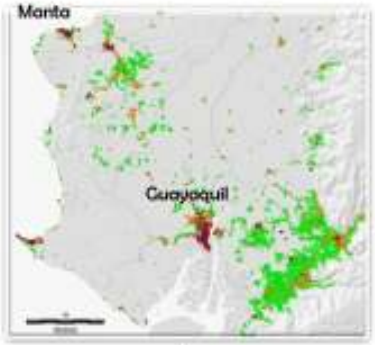
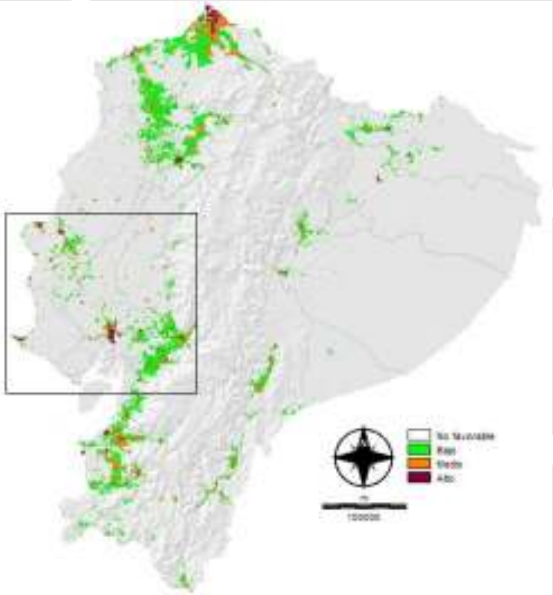
Modelación del impacto del cambio climático sobre riesgo



Uso de modelos de cambio climático para obtener temperatura y precipitación con los cuales se puede simular riesgo a futuro







Tipo de Zona favorable para A. a.	Población expuesta (millones)
Bajo	0.76
Medio	1.75
Alto	4.8