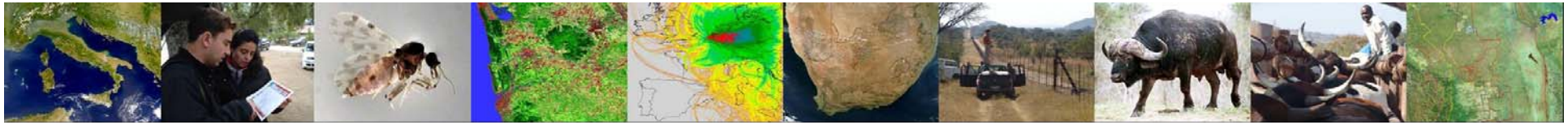
# Integrating remote sensing data in an agent-based model applied to spatial epidemiology

EPISTIS

Dion E., Vanhuysse S., Van Schalkwyk L., De pus C.,
De Clercq E, Wolff E., Lambin E.



epiSTIS

# Outline

- Spatial epidemiology
- Case study:  fringe of the Kruger National Park
  - Epidemiology
  - Spatial dimension
  - Data collection
- ABM
  - Definition
  - EPIFMD model
  - Model exploitation
  - EPIFMD and remote sensing
- Integration: STIS

ULB AviaGIS University of Pretoria

epiSTIS

# Spatial epidemiology

**Spatial epidemiology = description and analysis of geographic variations in distribution of diseases risks** (Ostfeld et al., 2005)

Epidemiology

Infection data

Spatial

RS, GIS

Development of new tools to understand the influence of spatial heterogeneity on disease transmission

Developement of a STIS (Spatial and Temporal Information System), tool to improve disease management

ULB

AviaGIS

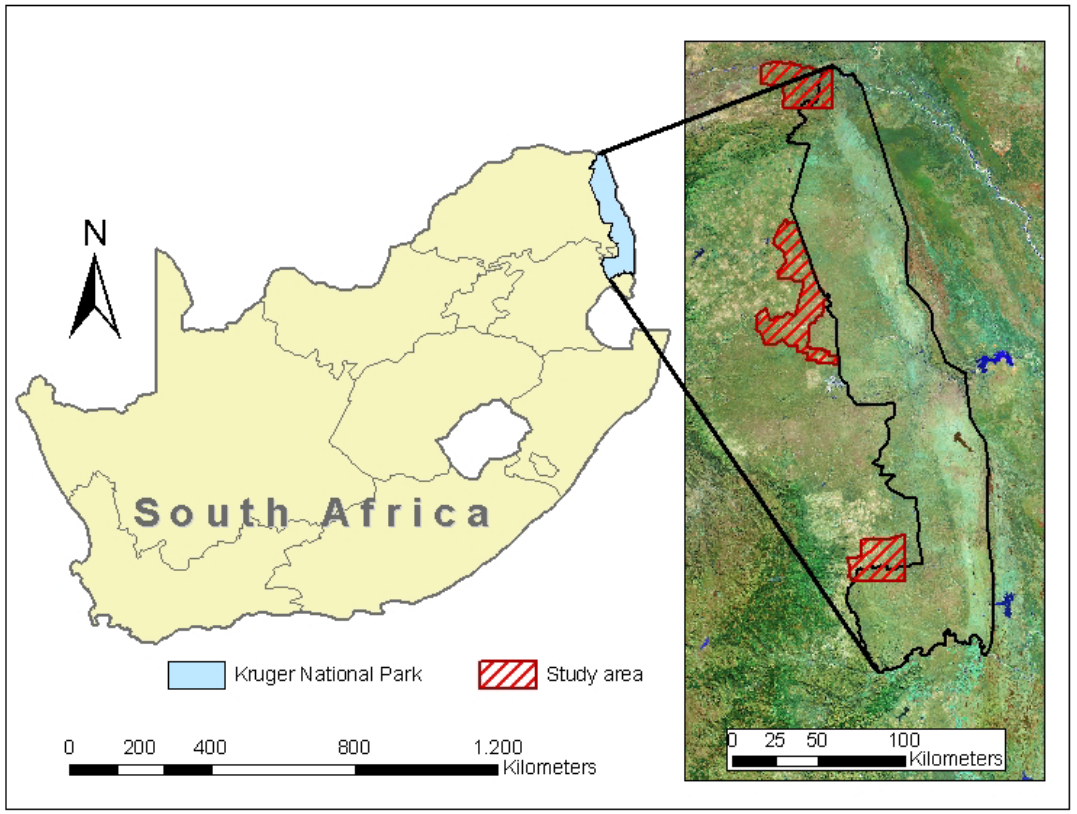
University of Pretoria

Belgian Science Policy

epiSTIS

# Case study

- Study area: Fringe of a large wildlife conservation area: Kruger National Park (KNP)
- Human-livestock-wildlife interface
- 3 small study sites of ±3000 km²
- Highly contagious veterinary disease: foot-and-mouth disease (FMD)




ULB

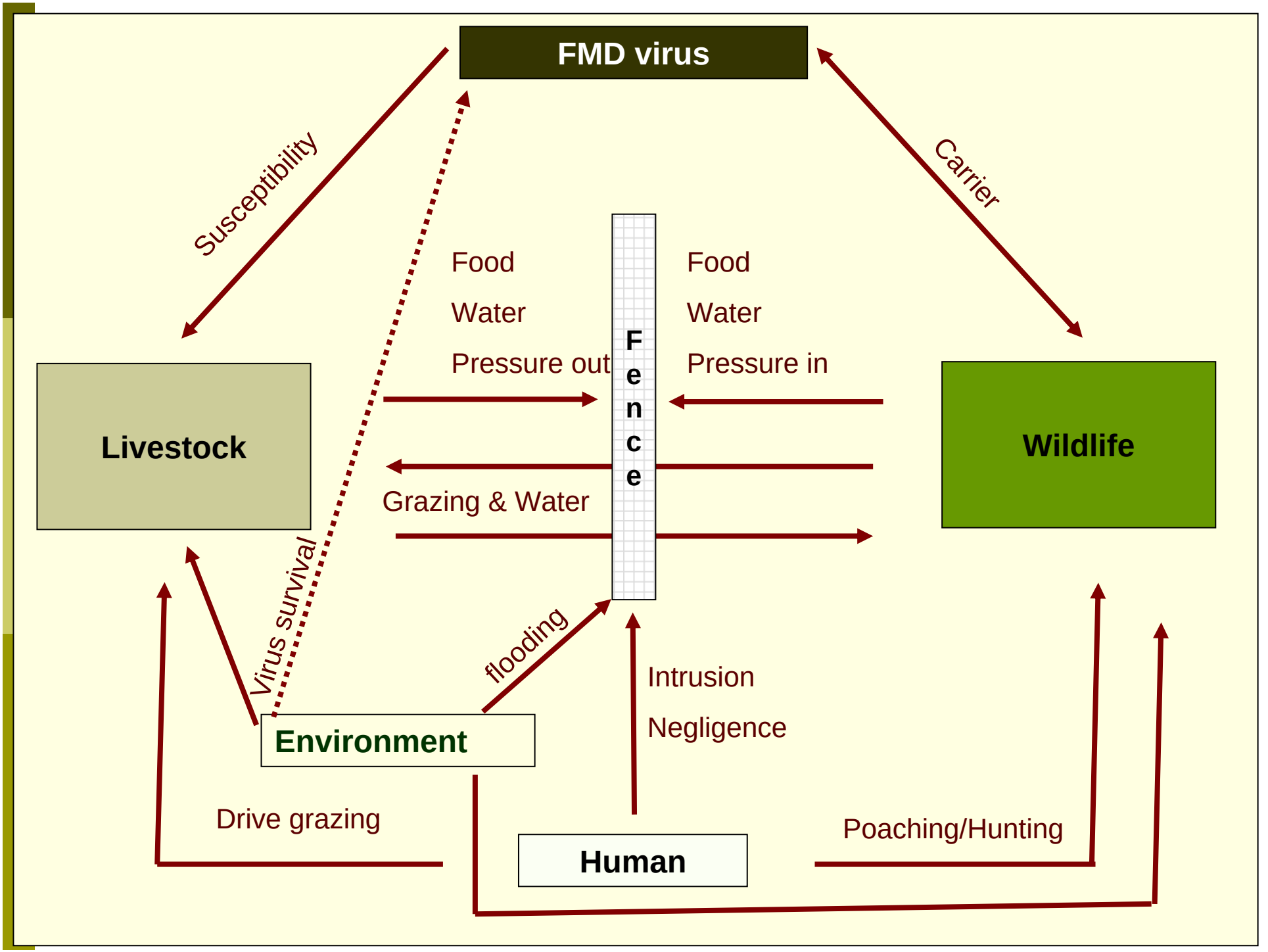
# Case study – Epidemiological aspect

- Infection transmitted from buffaloes (*syncerus caffer*) to cattle, near shared water points and rangelands (link with climatic conditions)
- Areas with a traditional land management system
- KNP: endemic region for FMD because buffaloes are carriers/reservoirs of the virus


- Around KNP, cattle is controlled once per week in a “dip tank” (inspection point)
- Cattle vaccinated twice per year (not full efficacy)

# Case study – Epidemiological aspect (2)

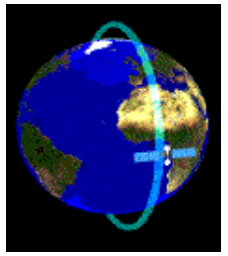
- KNP is fenced to separate cattle from infected wildlife
- Fences are permeable due to flooding, erosion, elephants, humans, open gates...


FMD virus
Susceptibility
Carrier
Food
Water
Pressure out
Food
Water
Pressure in
Fence
Livestock
Wildlife
Grazing & Water
Virus survival
flooding
Intrusion
Negligence
Environment
Drive grazing
Human
Poaching/Hunting

epiSTIS

# Case study – Spatial aspect

Complementary earth observation data



VHRRS

(IKONOS)

- Very High Spatial Resolution
- No Temporal Resolution
- Feature identification (factors that drive the movement/density )

HRRS

(SPOT)

- High Spatial Resolution
- Low Temporal Resolution
- Landscape analysis

L/MRRS

(MODIS, SPOT VEGETATION)

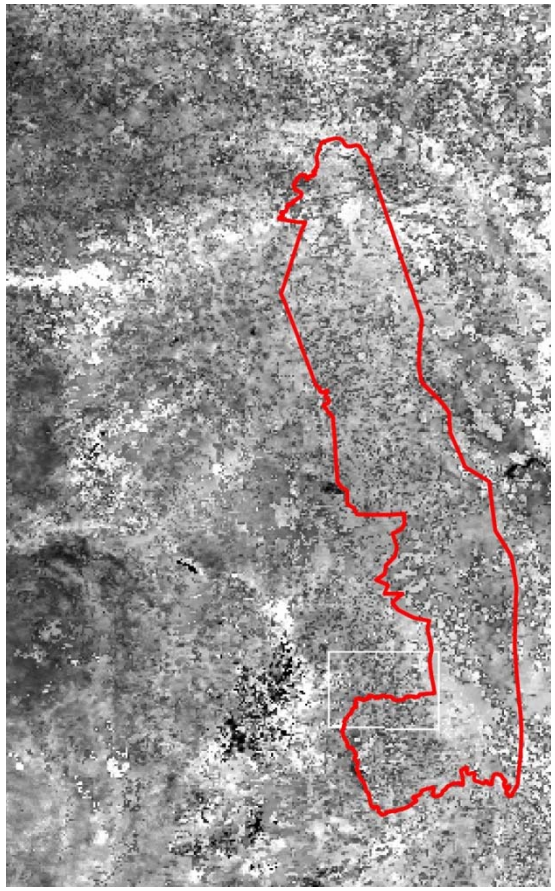
- Low Spatial Resolution
- High Temporal Resolution
- Eco-climatic time series

ULB AviaGIS University of Pretoria

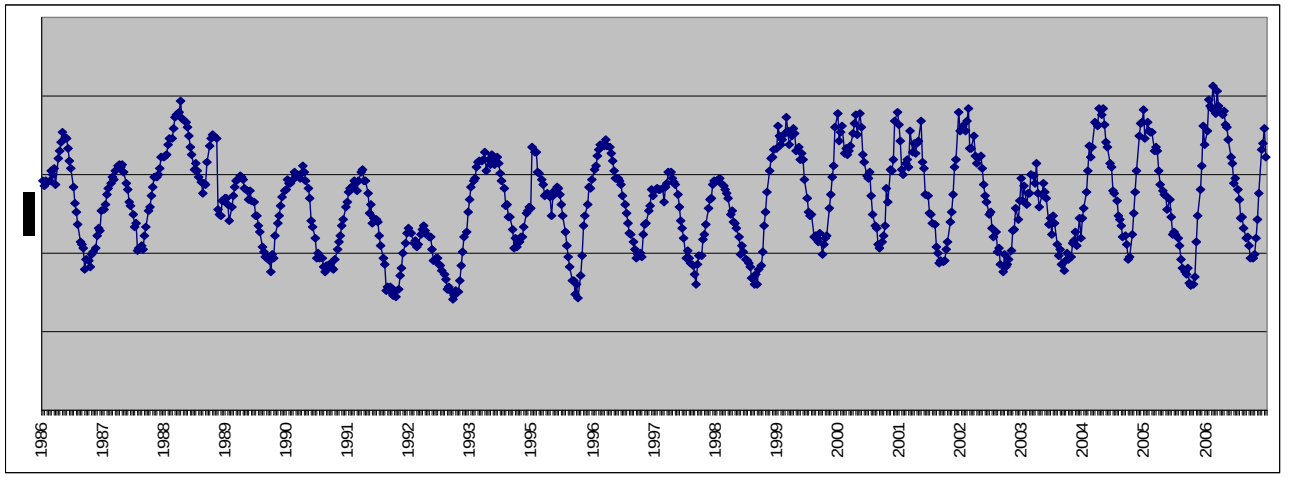
# Case study – Spatial aspect (2)

L/MRRS

Biomass, vegetation seasonality, interannual cycles, land surface moisture (via Ts), ...



NDVI of Spot vegetation (01/02/1985)



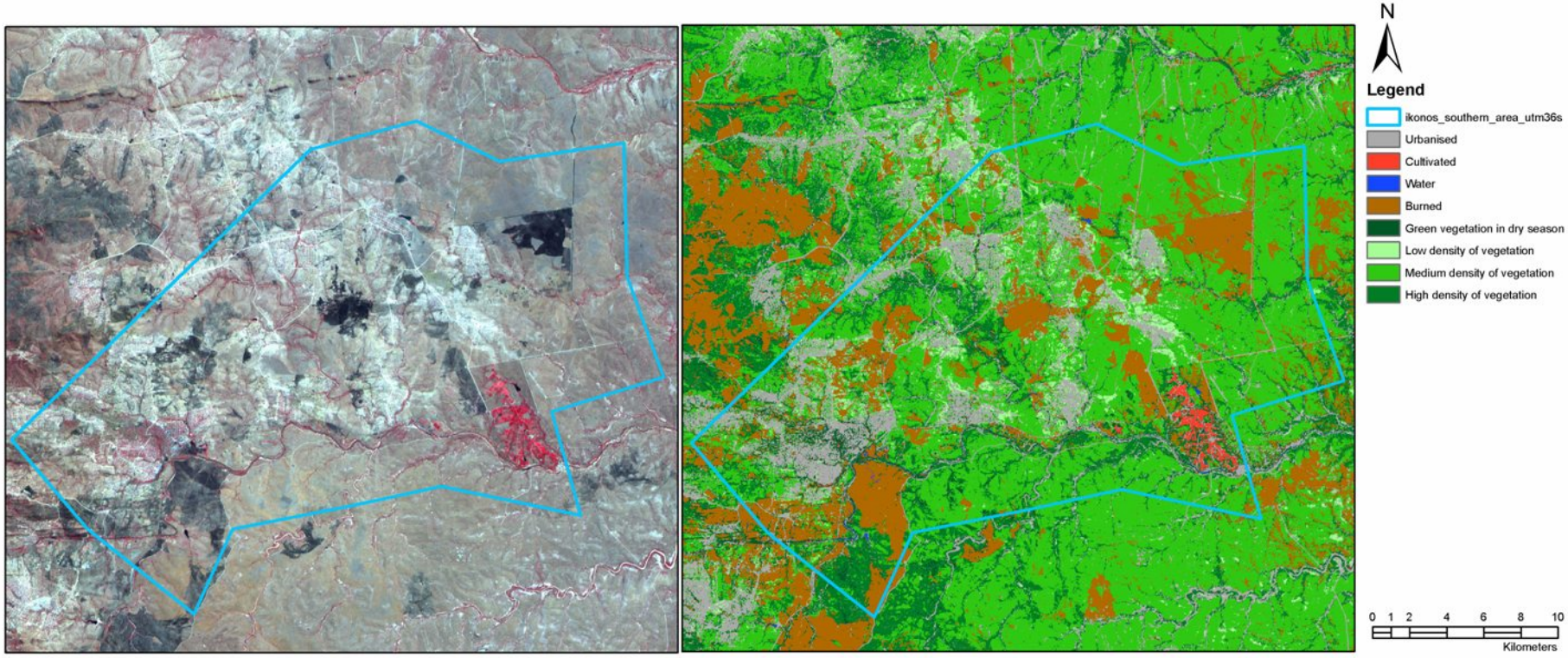

Processed Spot Vegetation data: Swinnen E., 2008 - Vegetation dynamics in Southern Africa from NOAA-AVHRR and SPOT-VGT time series, PhD thesis, UCL, 208p.

**GLOVEG Project**

# Case study – Spatial aspect (3)

HRRS

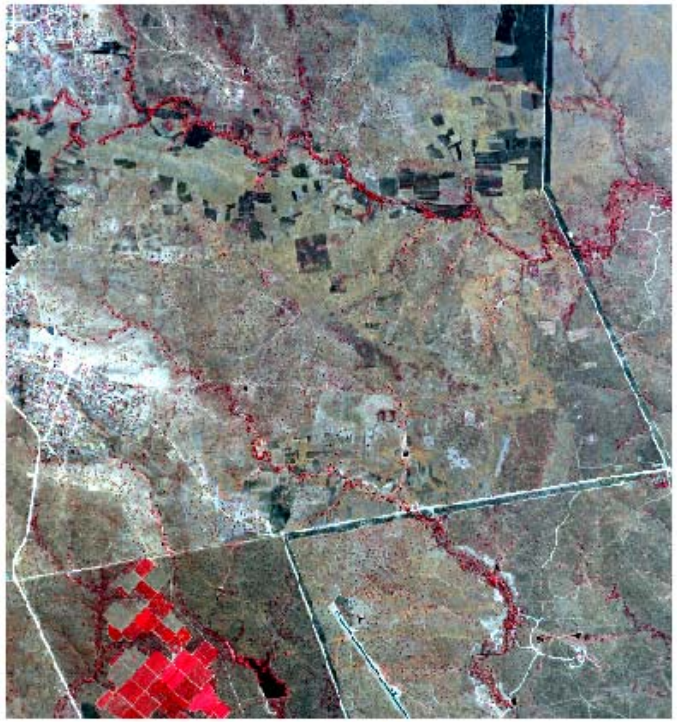
Land cover/land use maps, landscape fragmentation/connectivity, surface water bodies, ...

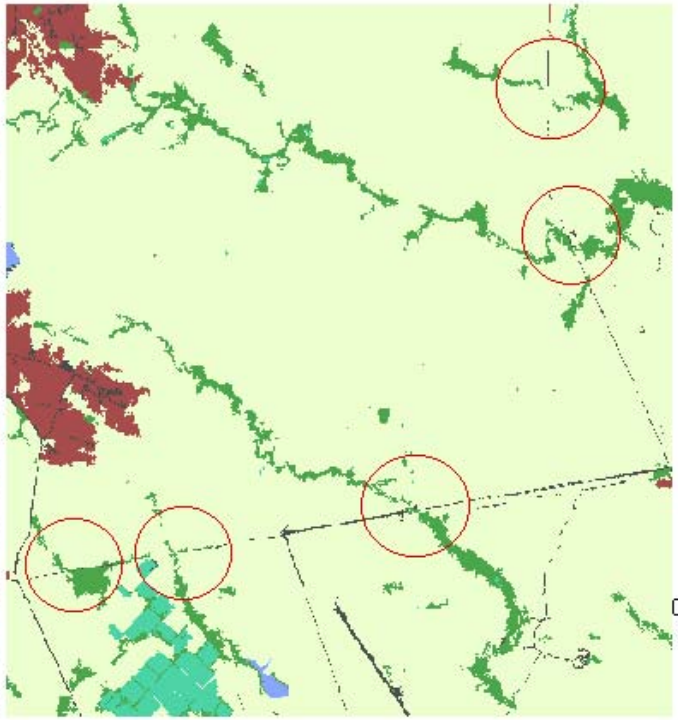


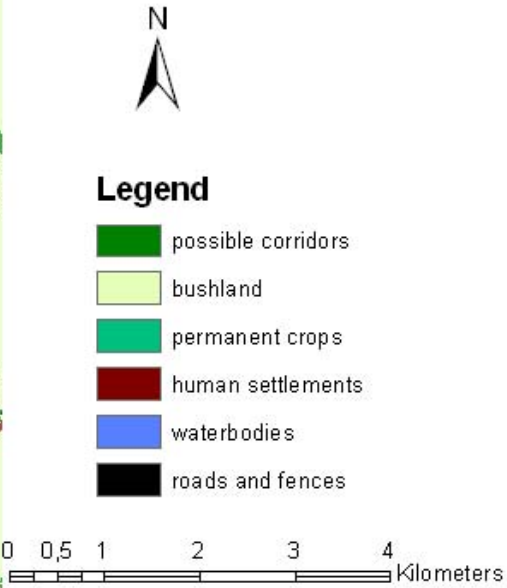
# Case study – Spatial aspect (4)

VHRRS

Human settlements, water bodies, migration corridors for wildlife, …



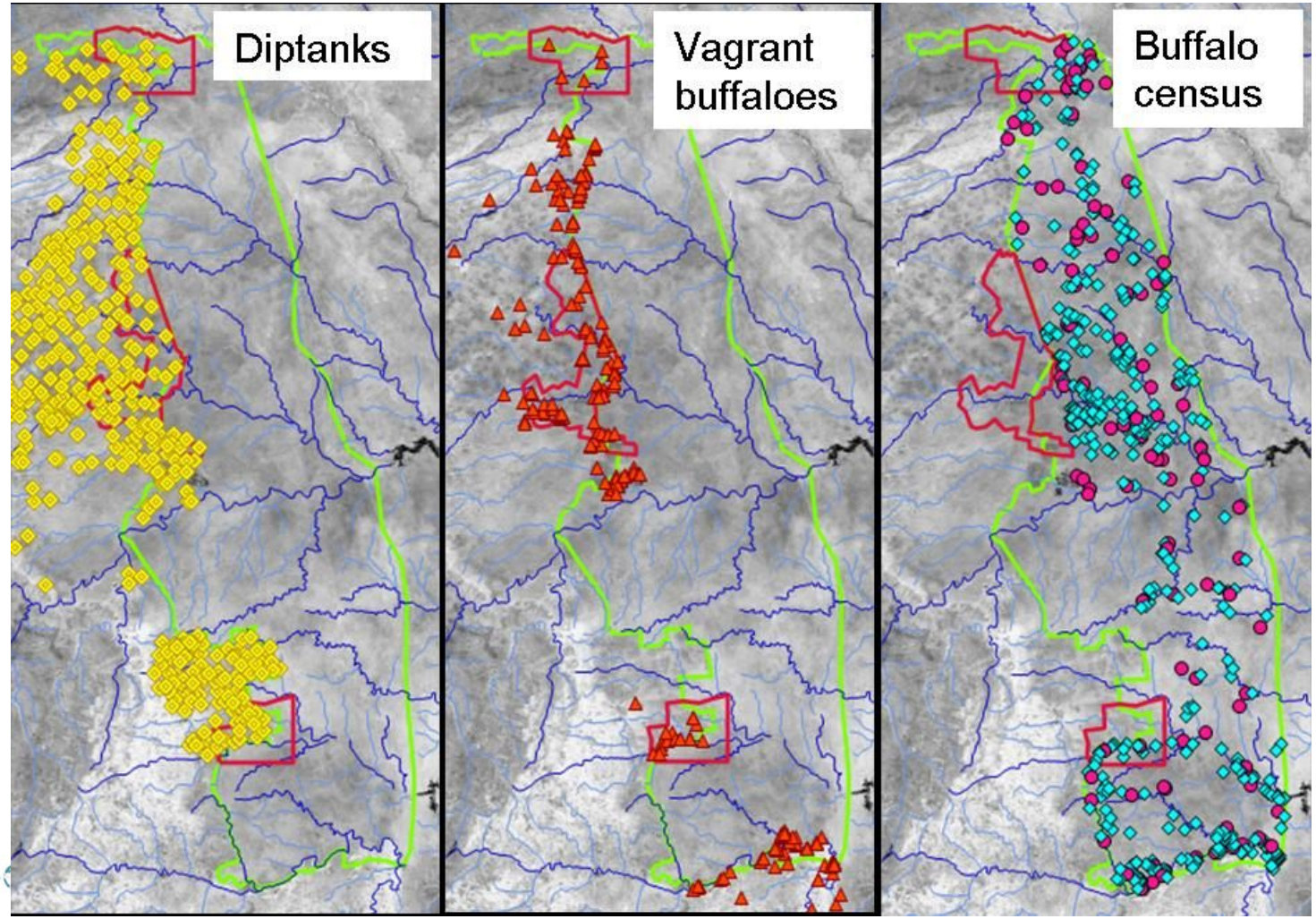




epiSTIS

# Data collecion

- Field data collection (Jun 07, Nov 07, Sep 08)
- Collaboration with vet technicians, collecting/capturing/cleaning decentralized data
- Cattle tracking




ULB

epiSTIS

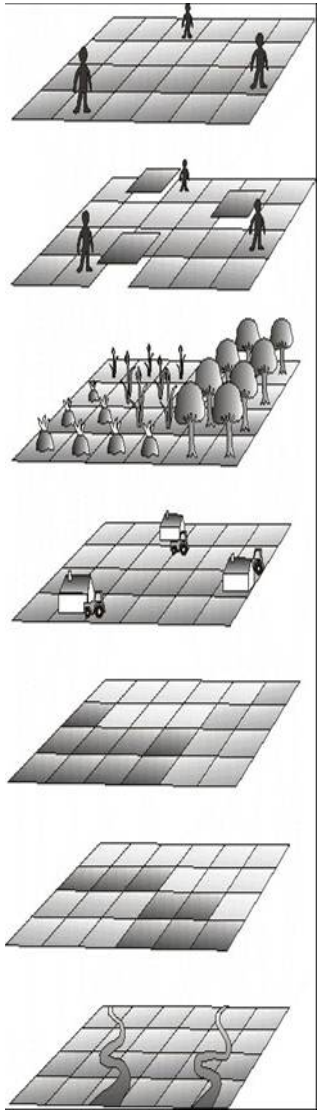
# ABM

Agent-based model

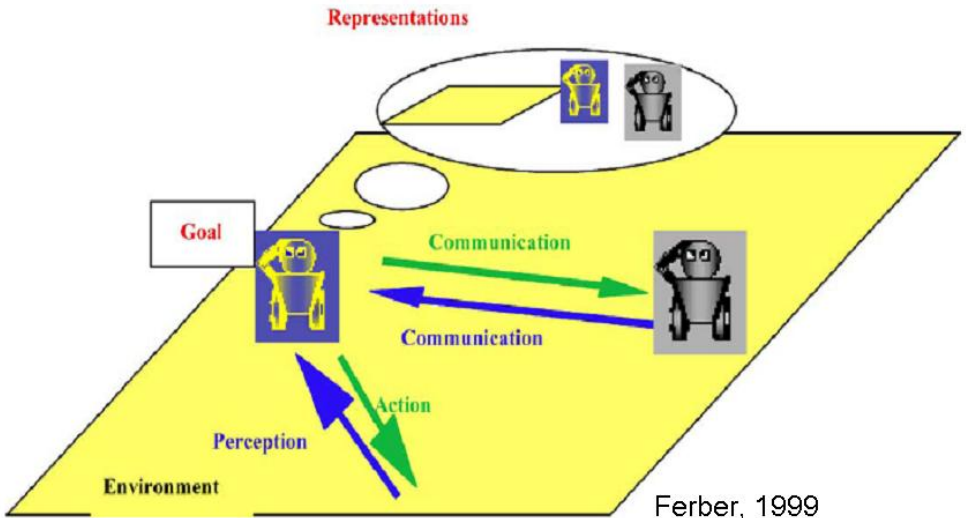
- Spatially-explicit model
- Combines RS, GIS, epidemiological, biological and socio-economic data
- Represents a complex system
- Risk maps based on various scenarios
- Integrates life sciences and spatial heterogeneity

**With multi-agent models, a problem can be analysed by: dividing a process into many components at the level of agents, representing the interplay between causes and effects, and feedback mechanisms.**

# ABM – Definition



- Composed by:
  - a spatially-explicit environment
  - autonomous individuals who move, interact, communicate, …
  - rules: interactions between individuals and their environment, adaptation and change over space and time

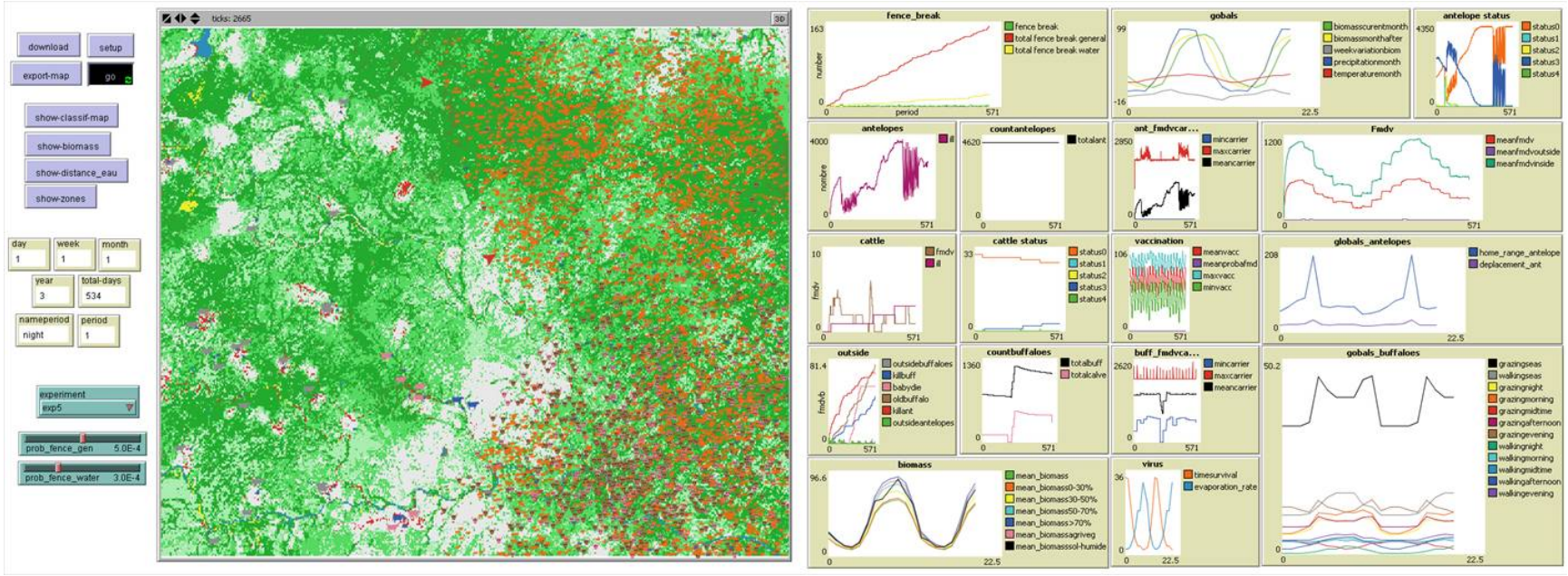


Ferber, 1999

- Virtual laboratory to test hypotheses with simulations

# ABM – EPIFMD

- Purpose
  - To simulate direct contact rate between buffaloes and cattle through space and time
  - To analyse and describe the factors that influence variations in contact rate and FMD outbreaks

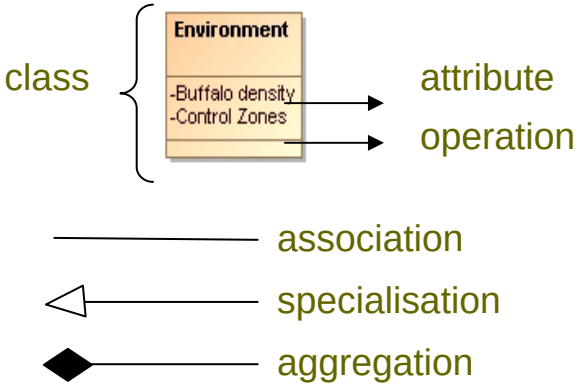



- Rules derived from data to mimic reality → simple micro-level rules generate macro-level phenomena

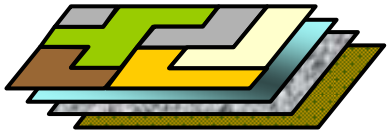
# ABM – EPIFMD

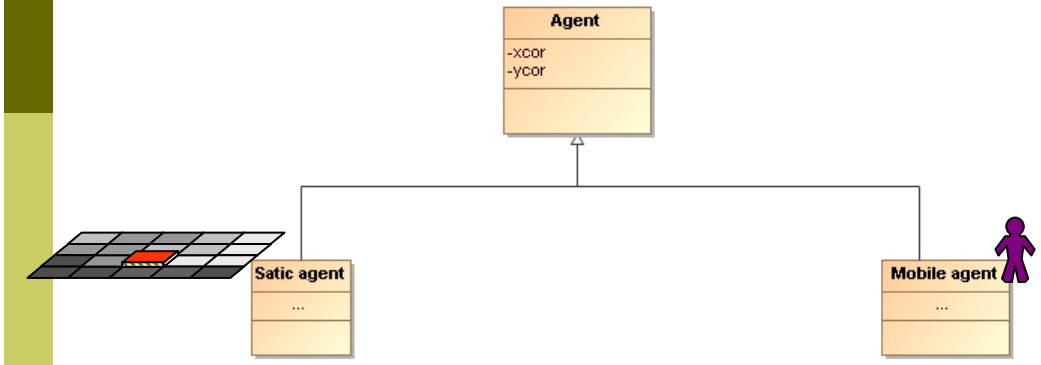
- Spatial and temporal scales
  - Spatial grid with 100 x 100 m pixels
  - Time-step: 1/5 of a day (night, morning, midday, afternoon, evening)
  - Time-steps aggregated in days, weeks, months, years → seasonality

- UML (Unified Modelling Language)
  - Conceptual representation of models with detailed description
  - Facilitate communication
  - Class diagram : static structure of the model



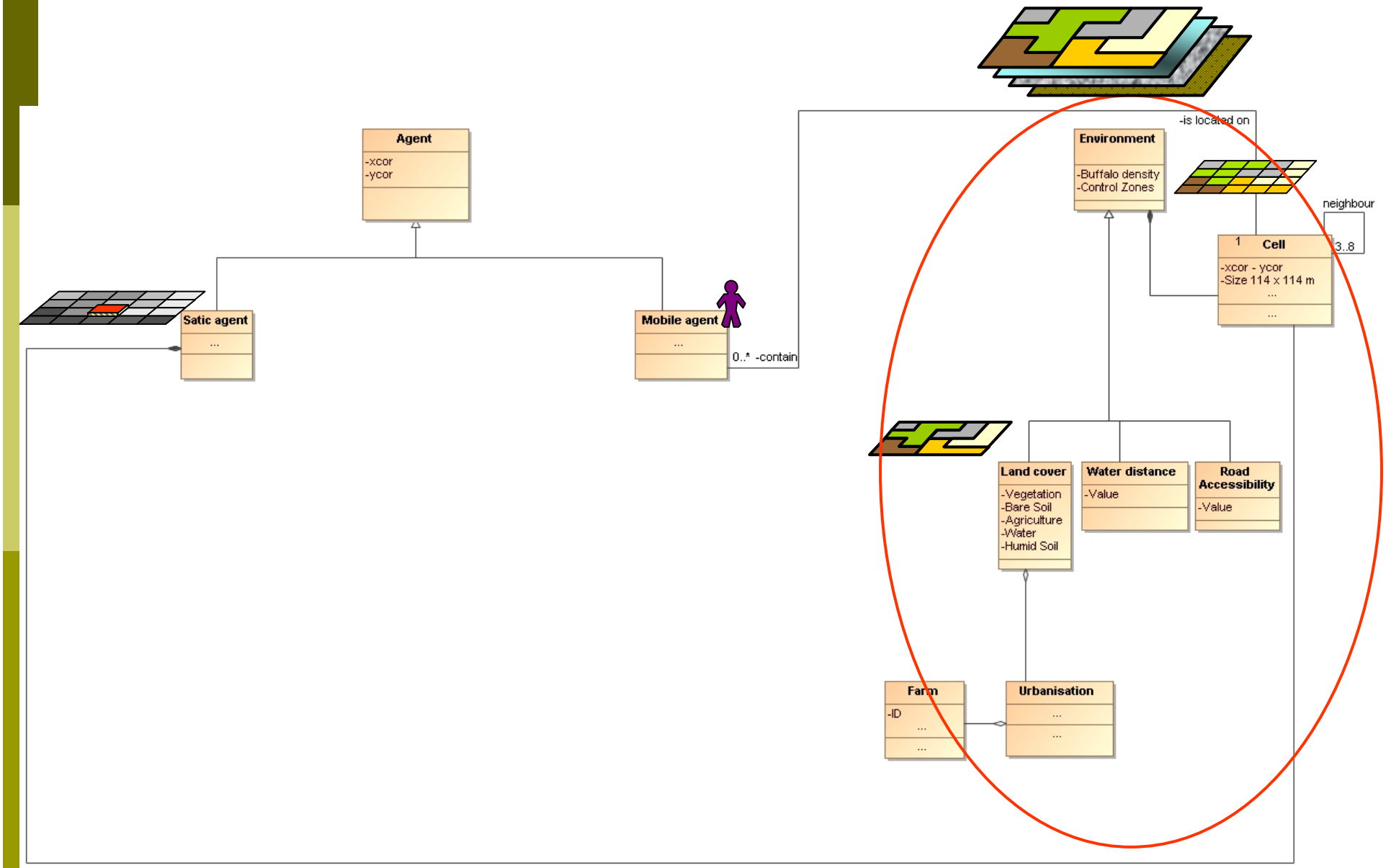
# ABM – EPIFMD

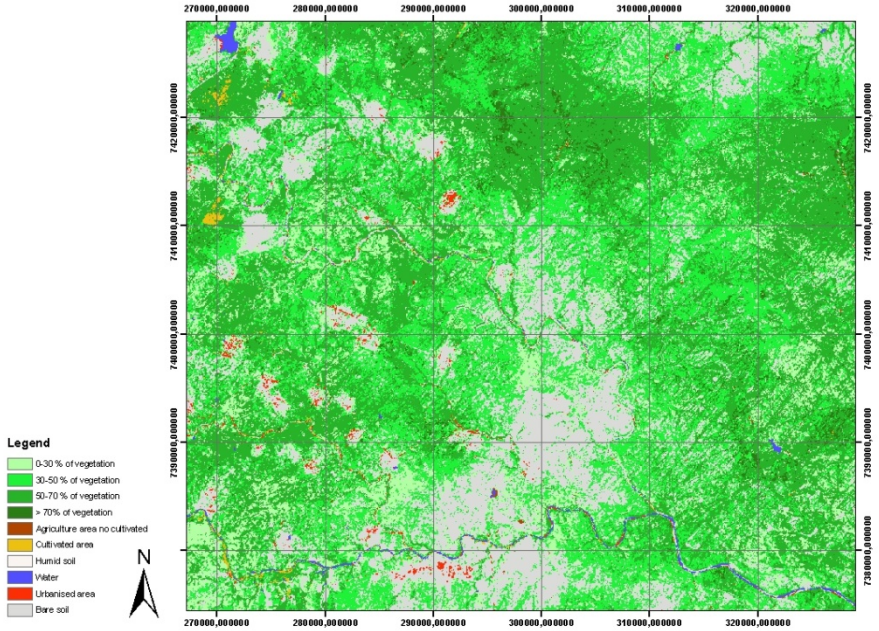


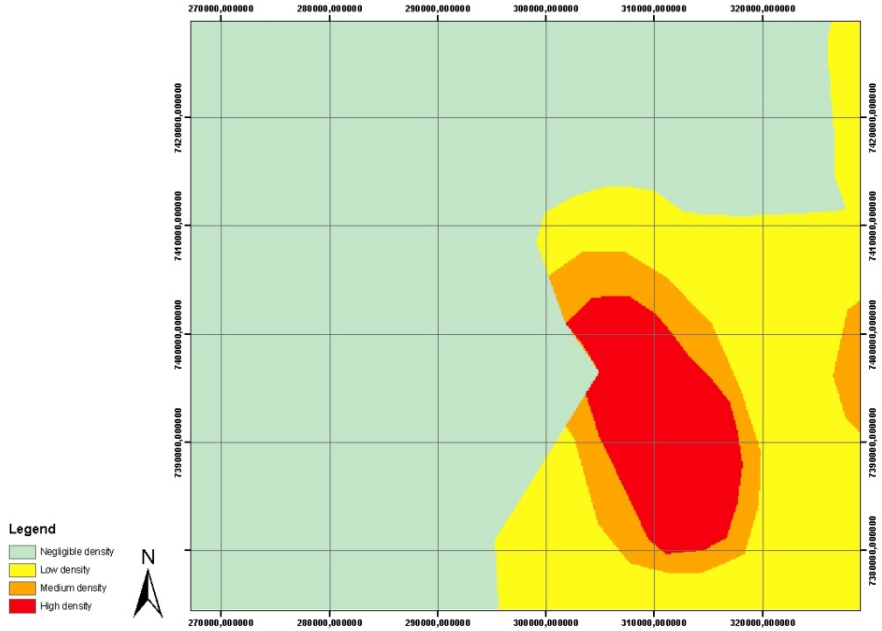

Agent
-xcor
-ycor
Satic agent
...
Mobile agent
...

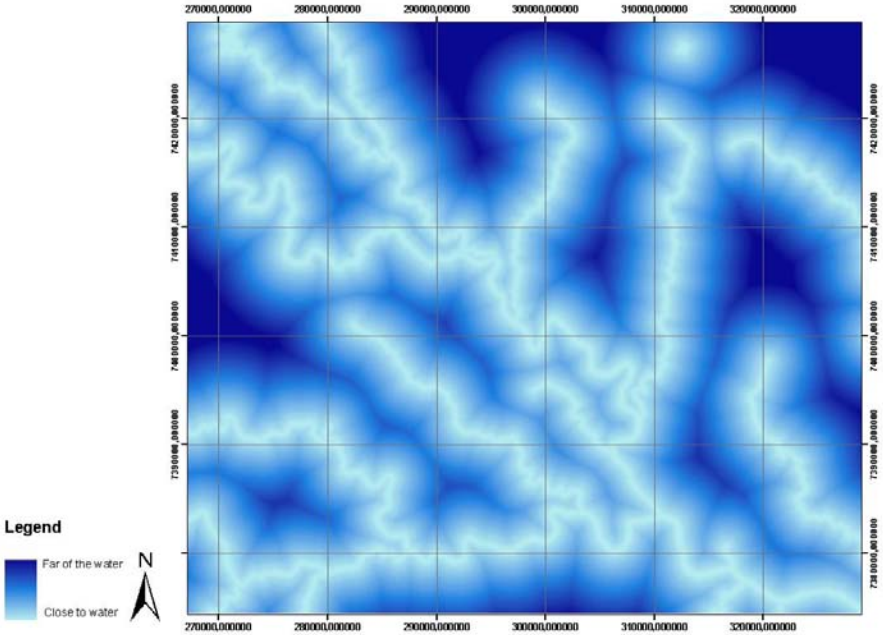

Environment
-Buffalo density
-Control Zones

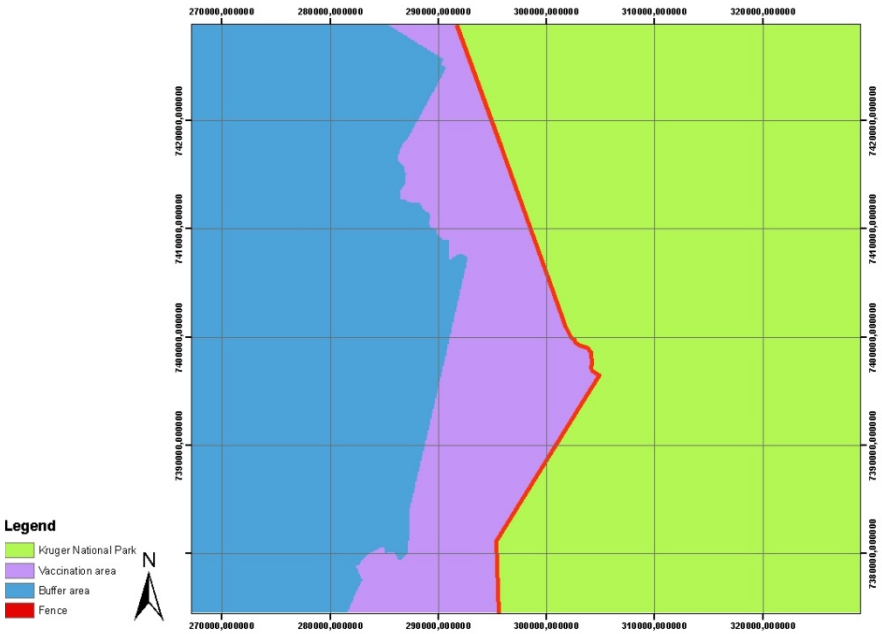
# ABM – EPIFMD


Agent
-xcor
-ycor
Satic agent
...
Mobile agent
...
0..* -contain
-is located on
Environment
-Buffalo density
-Control Zones
neighbour
1
Cell
-xcor - ycor
-Size 114 x 114 m
...
...
3..8
Land cover
-Vegetation
-Bare Soil
-Agriculture
-Water
-Humid Soil
Water distance
-Value
Road Accessibility
-Value
Farm
-ID
...
...
Urbanisation
...
...

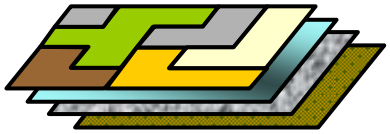

Legend
0-30 % of vegetation
30-50 % of vegetation
50-70 % of vegetation
> 70% of vegetation
Agriculture area no cultivated
Cultivated area
Humid soil
Water
Urbanised area
Bare soil
N
270000,000000
280000,000000
290000,000000
300000,000000
310000,000000
320000,000000
7420000,000000
7410000,000000
7400000,000000
7390000,000000
7380000,000000

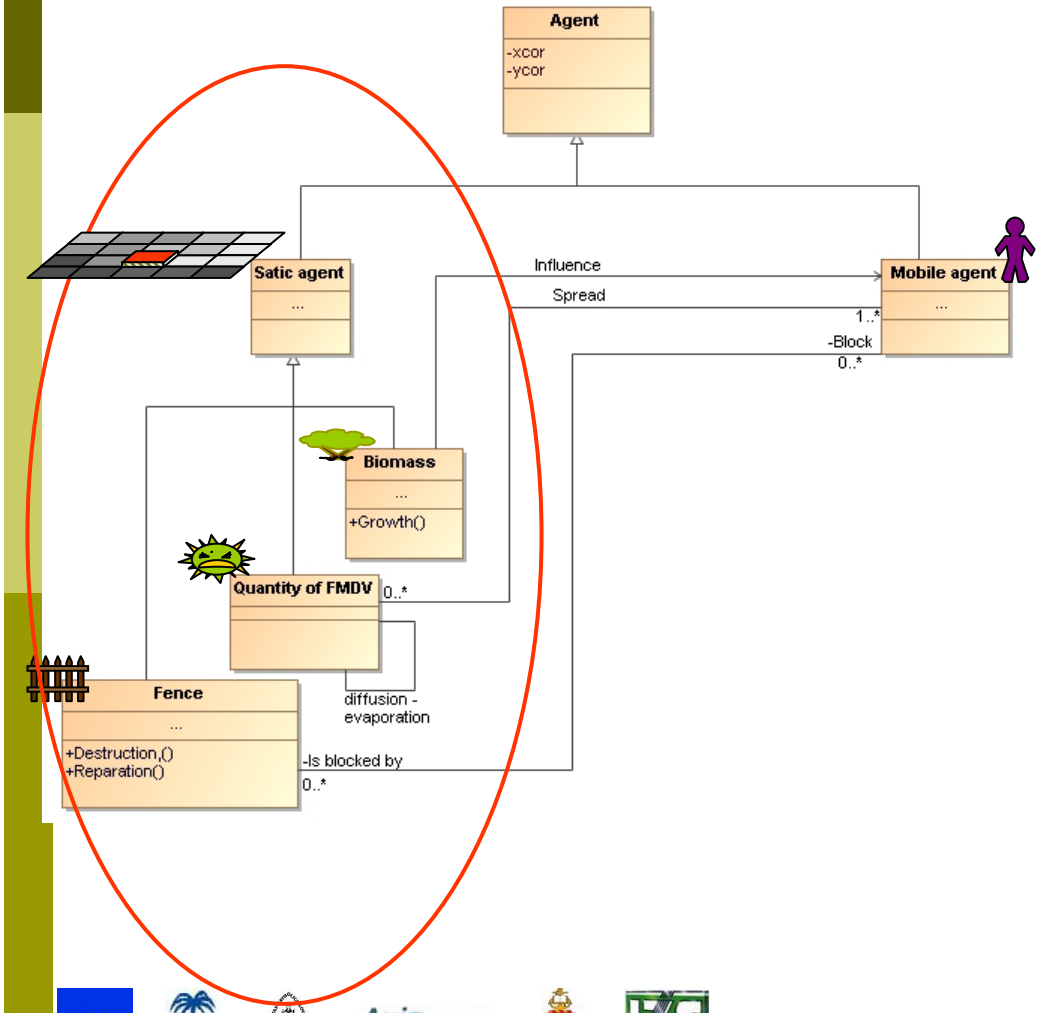

Legend
Negligible density
Low density
Medium density
High density
N
270000,000000
280000,000000
290000,000000
300000,000000
310000,000000
320000,000000
7420000,000000
7410000,000000
7400000,000000
7390000,000000
7380000,000000


Legend
Far of the water
Close to water
N
270000,000000
280000,000000
290000,000000
300000,000000
310000,000000
320000,000000
7420000,000000
7410000,000000
7400000,000000
7390000,000000
7380000,000000

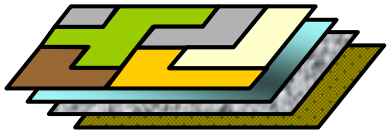

Legend
Kruger National Park
Vaccination area
Buffer area
Fence
N
270000,000000
280000,000000
290000,000000
300000,000000
310000,000000
320000,000000
7420000,000000
7410000,000000
7400000,000000
7390000,000000
7380000,000000

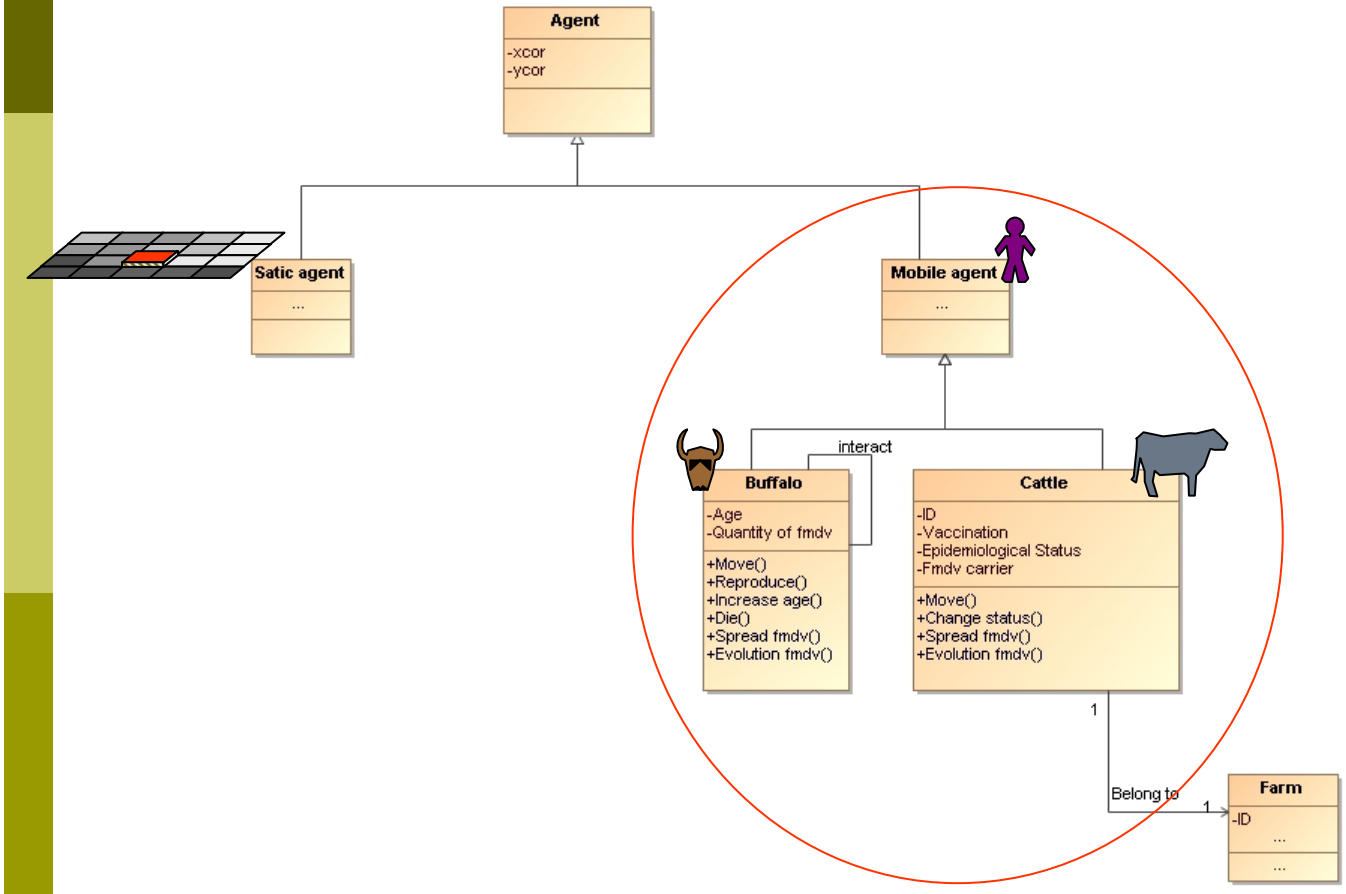
# ABM – EPIFMD




Agent
-xcor
-ycor
Environment
-Buffalo density
-Control Zones
Satic agent
...
Influence
Spread
Mobile agent
...
1..*
-Block
0..*
Biomass
...
+Growth()
Quantity of FMDV
0..*
diffusion -
evaporation
Fence
...
+Destruction,()
+Reparation()
-Is blocked by
0..*

# ABM – EPIFMD

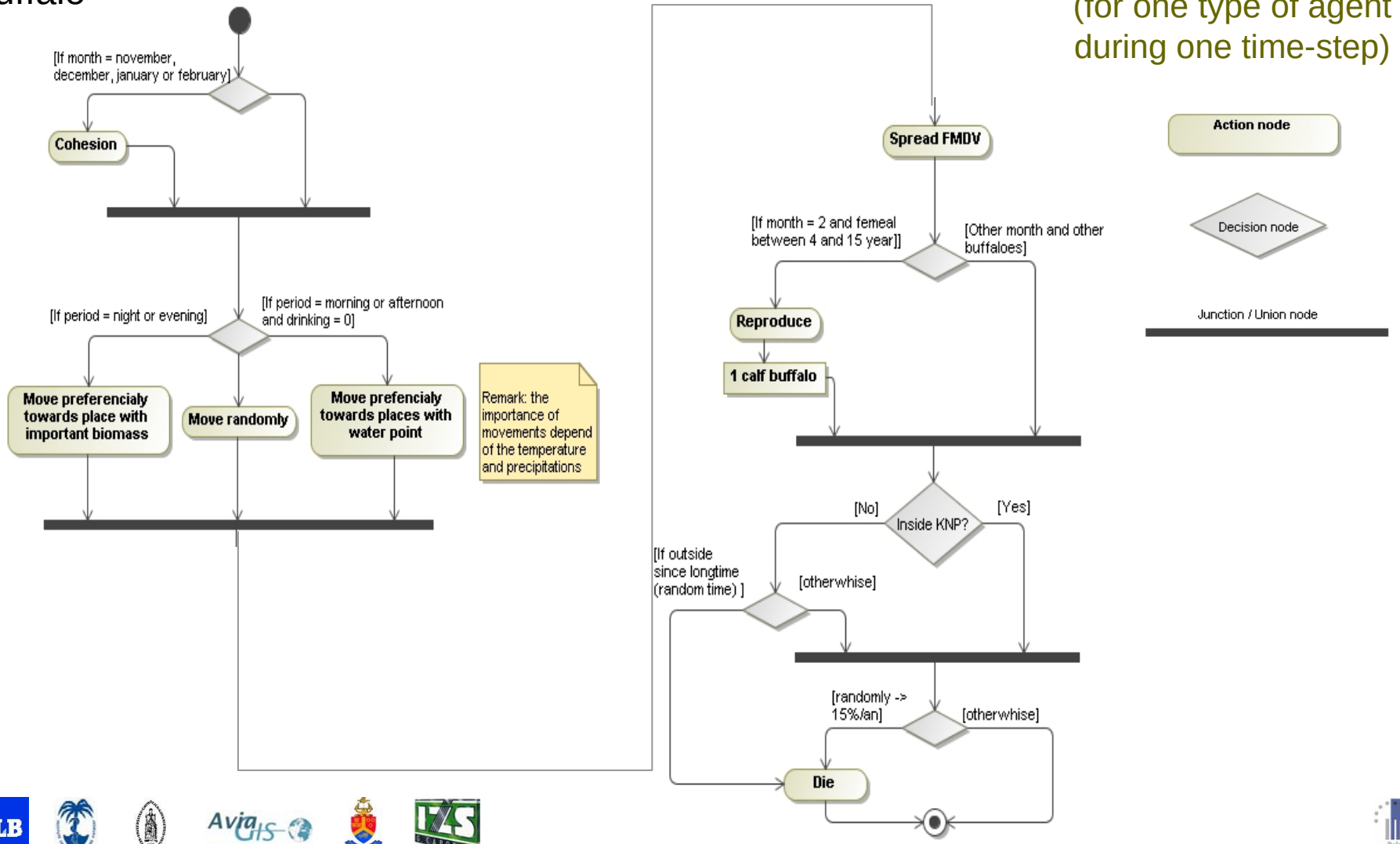



Agent
-xcor
-ycor
Environment
-Buffalo density
-Control Zones
Satic agent
...
Mobile agent
...
interact
Buffalo
-Age
-Quantity of fmdv
+Move()
+Reproduce()
+Increase age()
+Die()
+Spread fmdv()
+Evolution fmdv()
Cattle
-ID
-Vaccination
-Epidemiological Status
-Fmdv carrier
+Move()
+Change status()
+Spread fmdv()
+Evolution fmdv()
1
Belong to
1
Farm
-ID
...
...

# EPIFMD development

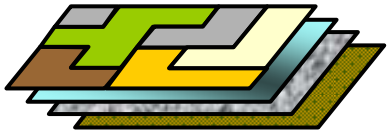
Activity diagram:
succession of actions
(for one type of agent
during one time-step)

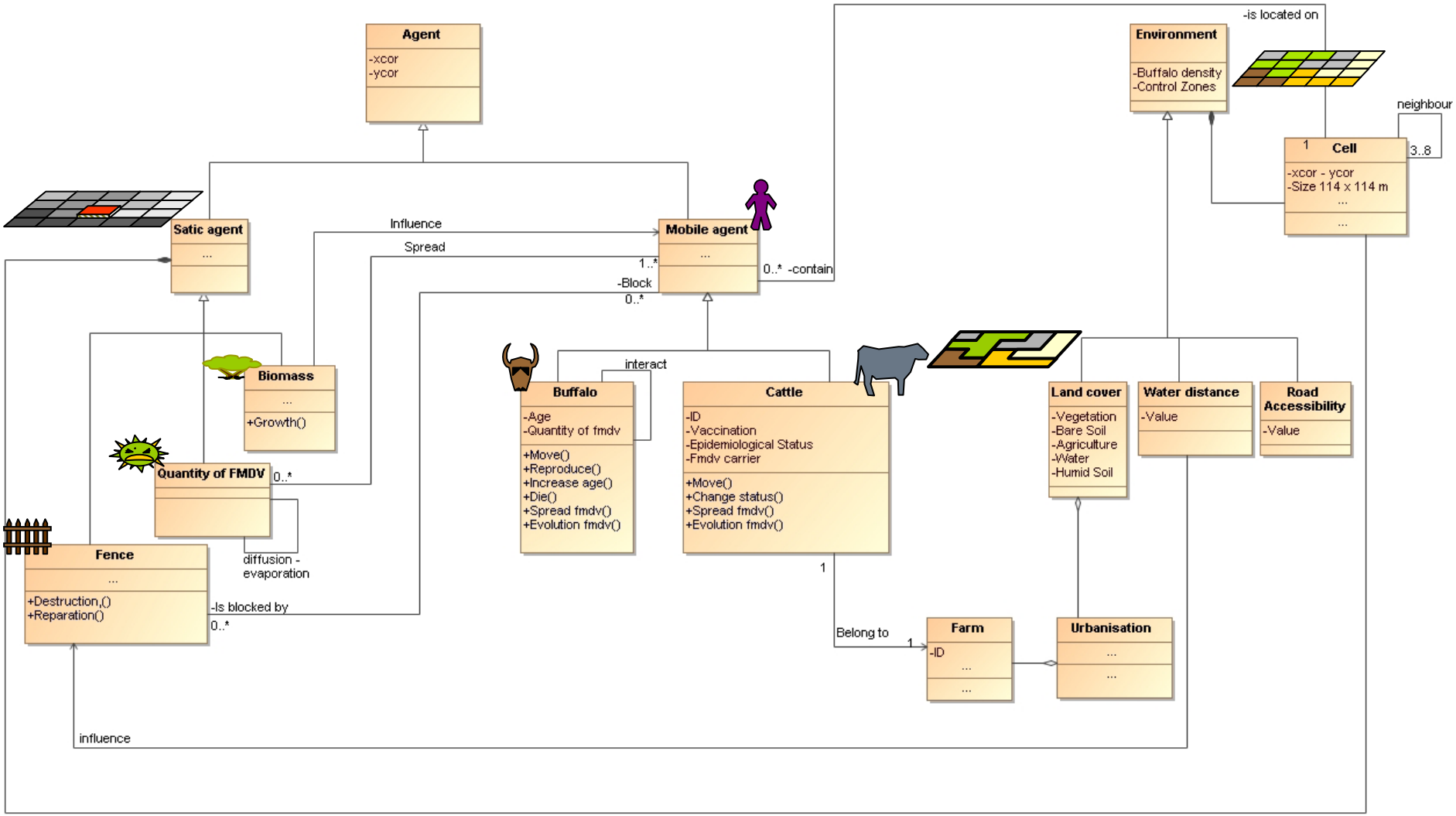
Buffalo



epiSTIS

# ABM – EPIFMD





# ABM – Model exploitation

- Calibration of variables/parameters and validation – verification combining various methods

- Testing scenarios on agent behaviour and environmental conditions:
  - to analyse the influence of various factors
  - to elaborate risk maps

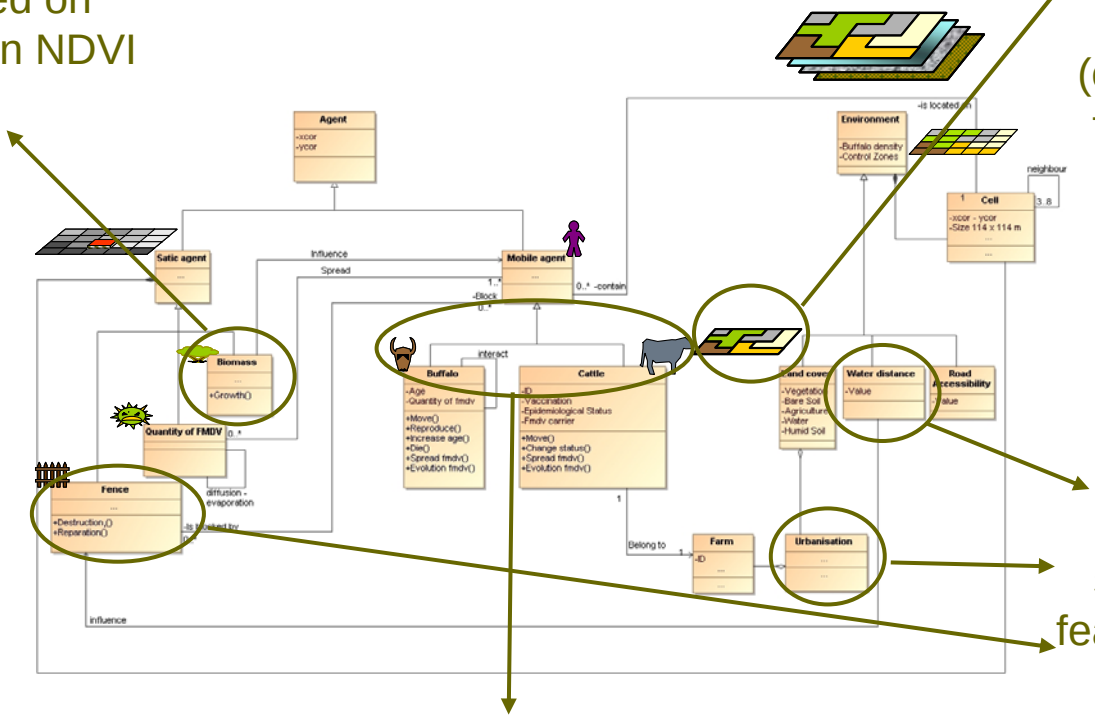
- Scenarios related to:
  - spatial fragmentation & heterogeneity
  - land-use changes
  - climate changes
  - socio-economic changes
  - behaviour of cattle owner
  - …

# EPIFMD and Remote sensing

RS provides key inputs to EPIFMD model

Biomass dynamics defined based on Spot Vegetation NDVI

Land cover map from HRRS provides environmental basis of EPIFMD (classification suited for model's needs)




VHRRS locate specific landscape features (water points, fence, habitats...)

Rules of animal behaviour and mobility based on RS observations (e.g. migration corridors for wildlife)

epiSTIS

# Integration: STIS

How can Earth Observation contribute to improve spatial analysis?

Spatial modeling

↓

Space-time dynamics of disease transmission

↓

Disease control strategies: prevent disease outbreaks and spread

↓

Improvement in the analysis and management of space-time dynamics of diseases by integrating results in a STIS