Combining mixture models and Markov chains to explore spatio-temporal dynamics of child wasting in southern Madagascar

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Plan

Plan

Undernutrition in Madagascar

- Madagascar, face regular Food Insecurity crisis especially in the south of the country.
- Study area correspond to the Big South where some place could take day to be joined from cities.
- Focus on child wasting (deficiency of muscle and fat), malnutrition type that need special attention for emergency care.
- One characteristic of such a country is the weak availability of data

Wasting

- Child Wasting is testing by comparing Weight / Height or Mid-upper arm circumference against a threshold.
- Test categorise child with Severe Acute Malnutrition (SAM) or Moderate Acute Malnutrition (MAM) and the sum is called General Acute Malnutrition (GAM).
- Notice that $\{SAM\} \subset \{GAM\}$
- GAM prevalence is considered as a markor of Food Insecurity whereas SAM prevalence may vary with health problem.
- For now we don't have a good "quantitative" representation of space and time variability for incidence or prevalence of Wasting in the study area.

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IPC Analysis

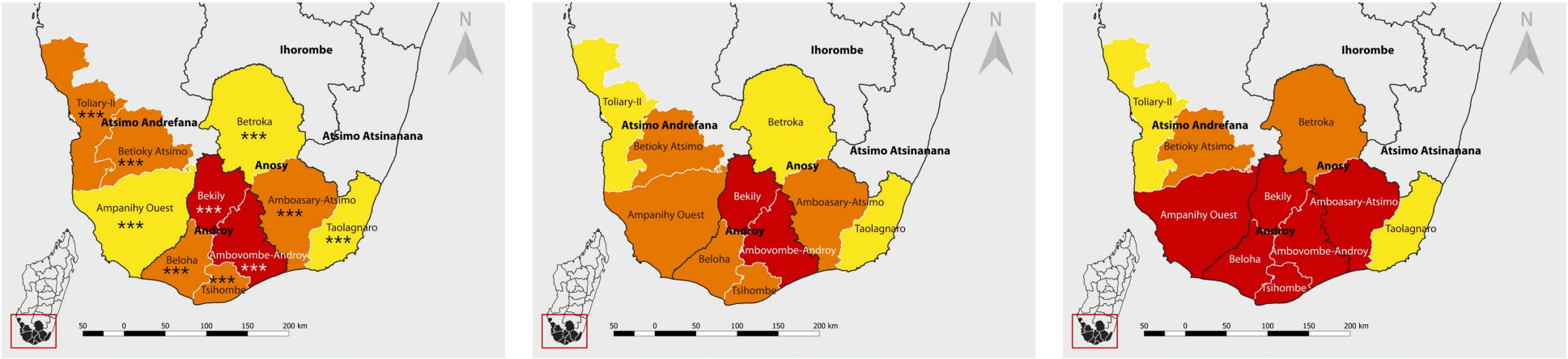
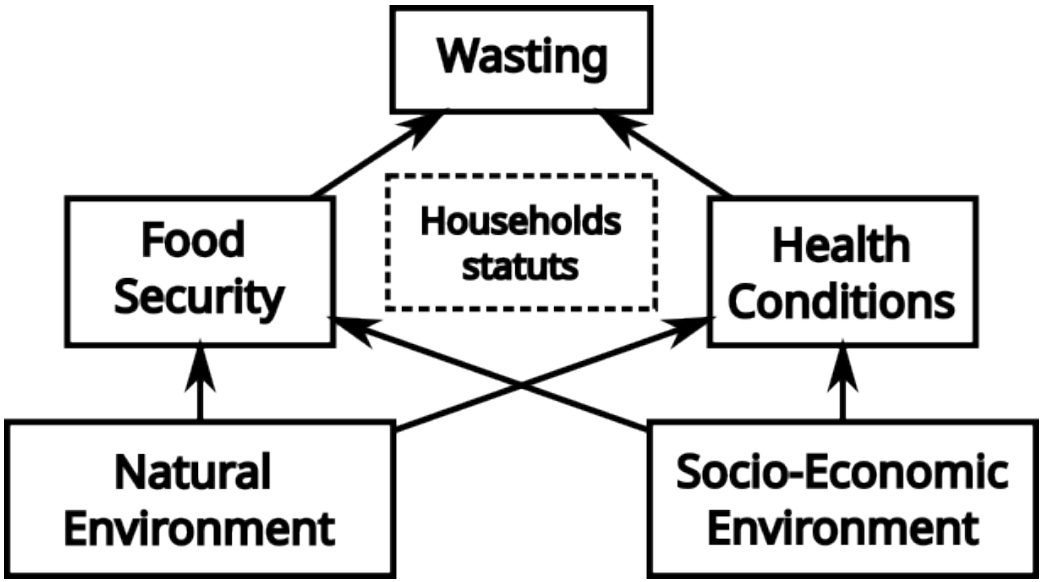


Figure: IPC Acute MaInutrition Classification 2021 : from left to right, Current May - August ; Projected September - December ; January - April

Early warning from current situation, normals knowledge and environmental contributing factors

Conceptual framework



From this framework with statistics we can improve knowledge on :

- Variables (*e.g.* distribution)
- Relations (*e.g.* regression)
- Evolution
- Spatial differences

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Exhaustive Surveys of Child Wasting prevalence

Some characteristics of the dataset :

- 2000 trimesters values / 6 years / maximum of 15 trimesters
- Fiability of the measure
- Good Spatial precision
- Sparcity and missing not at random
- T1 (Lean Season): 27% T2: 13% T3(Post Harvest season): 40% T4: 20%

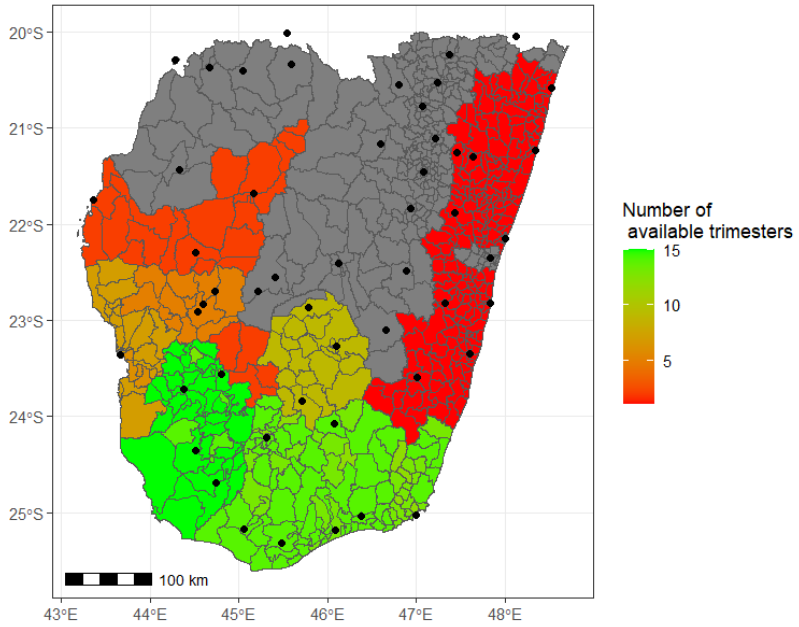

Figure: GAM Trimester prevalence availability

GAM Map example

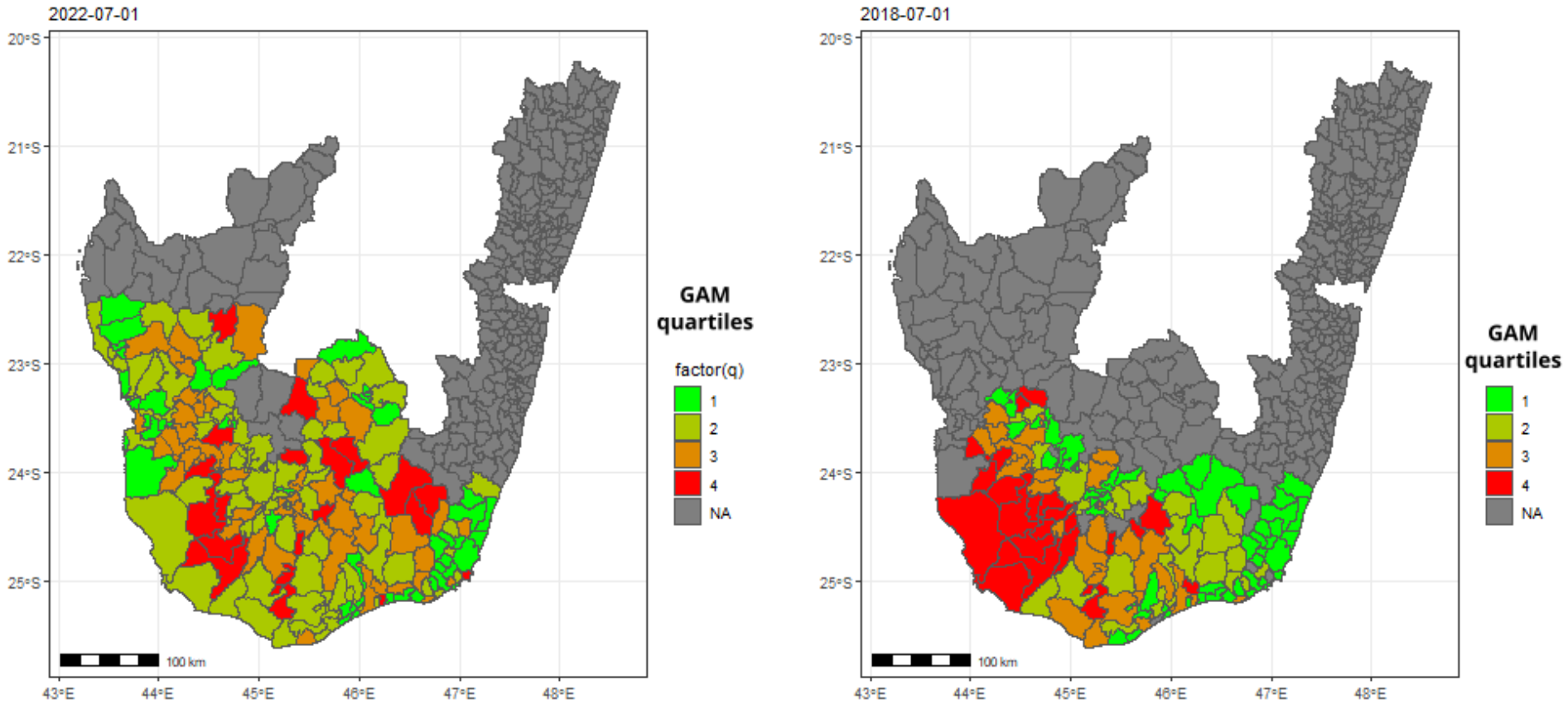

Figure: GAM prevalence maps categorised by quartiles of the whole distribution

SAM & GAM characteristics

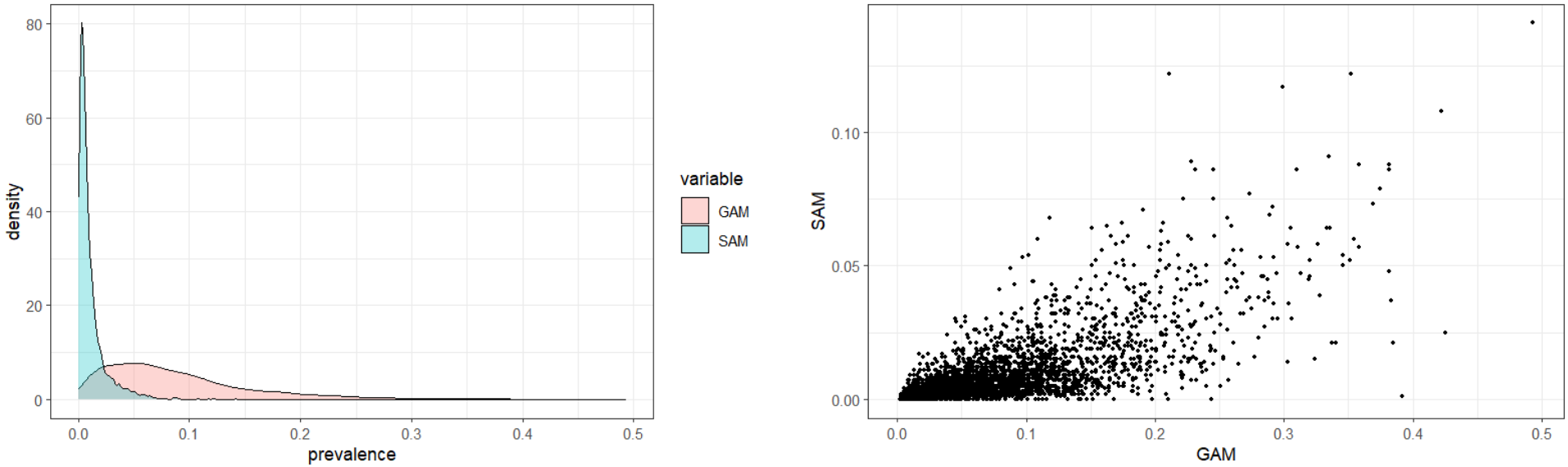

Figure: Left : density plots of GAM and SAM prevalence. Right : scatter plot of SAM vs GAM

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Model principles

We want to :

- mimic Human decision processus
- propose intelligible models for nether statistician, nor scientist
- give them theoretical knowledge about what they are doing

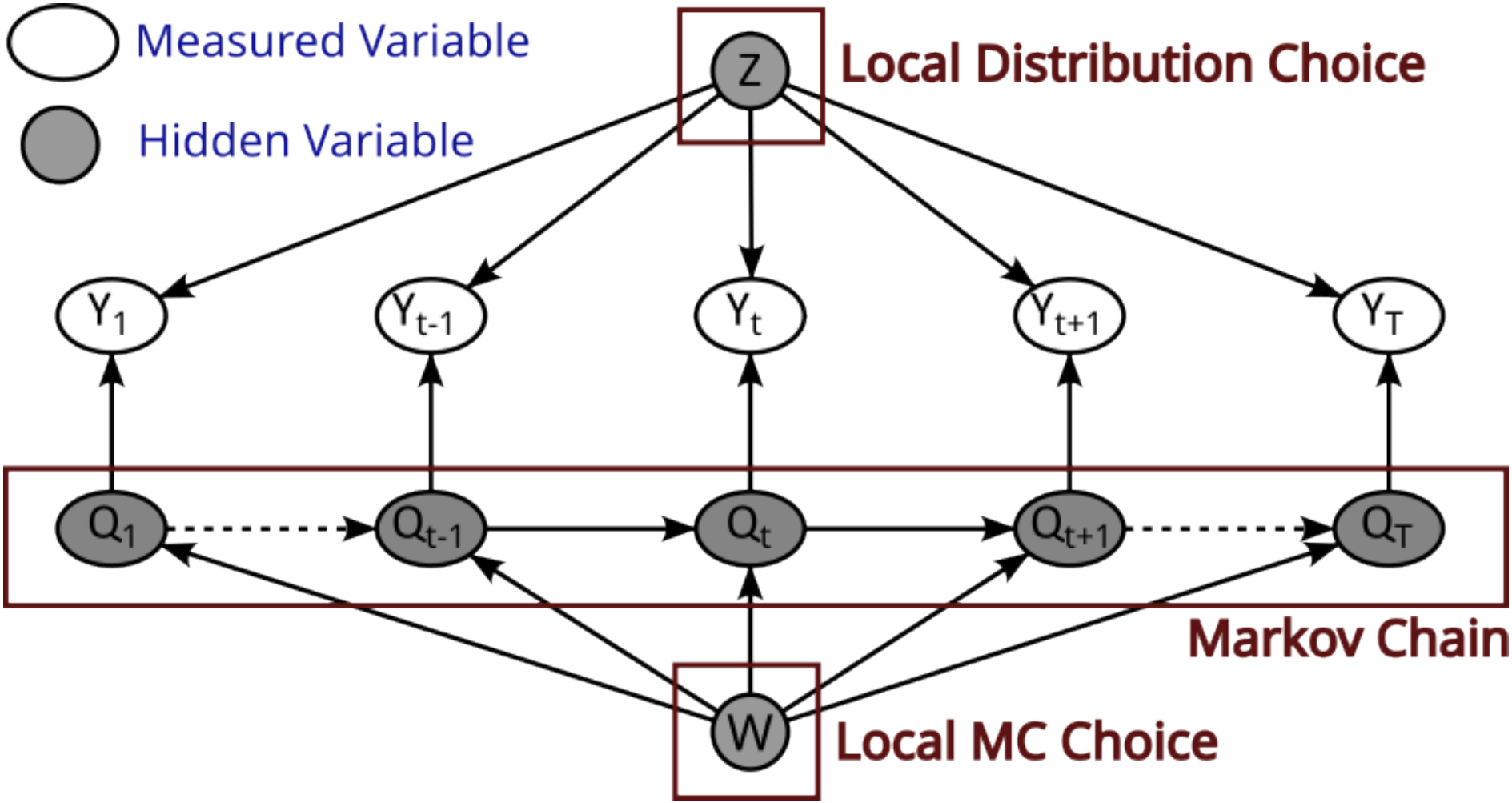
Constraints :

- Include all municipalities even if they have few datas
- Have a good statistical power
- Take account when data are produced (seasonality)

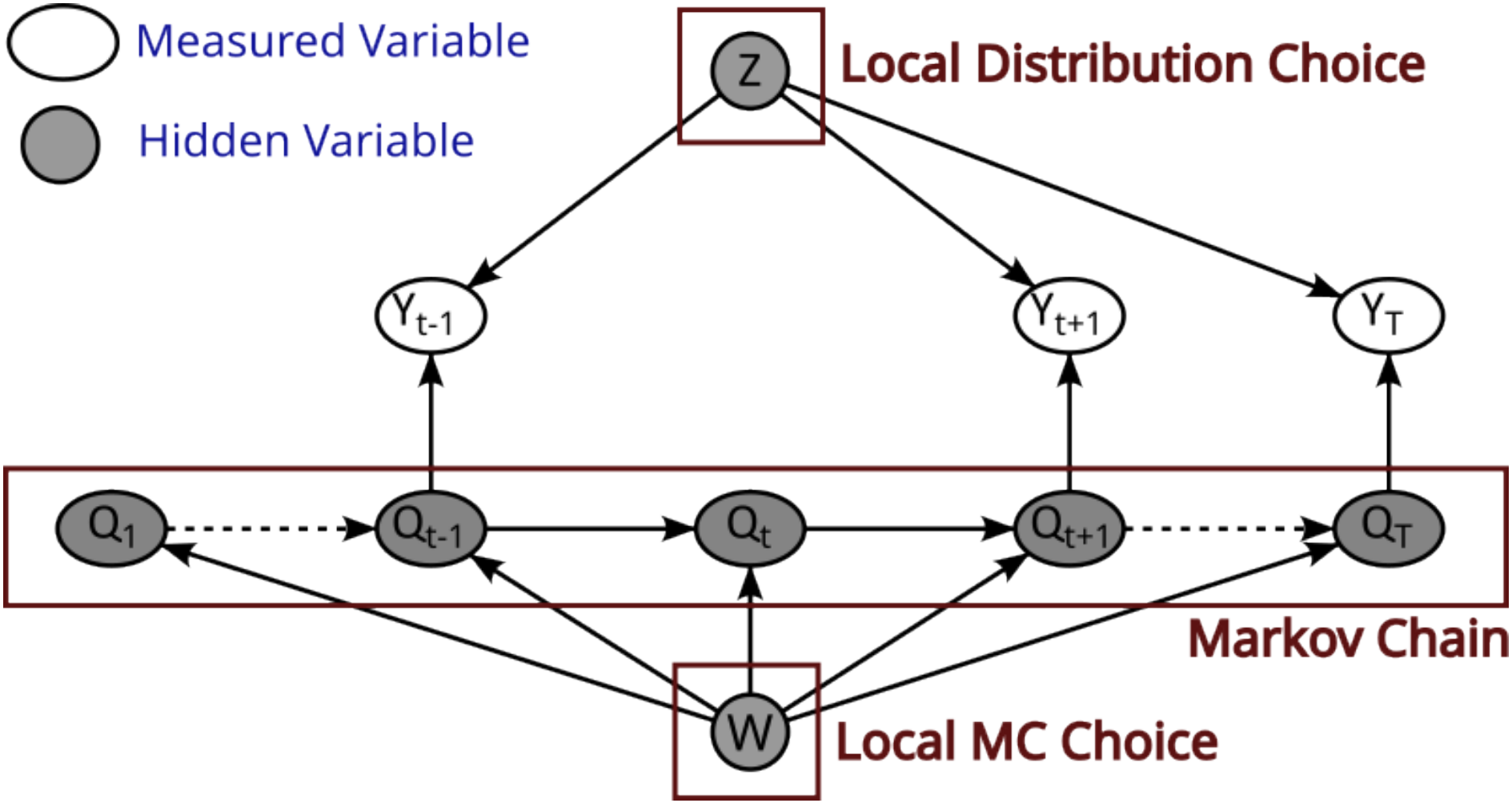
Solutions :

- Clustering with Beta Mixture
- Work on time transition with "periodic, time-inhomogeneous Markov chains"
- 2 type of model : "1d" for GAM or SAM and 2d for a join (GAM, SAM) vector.

Model with classical HMM



Our Model


Measured Variable
Hidden Variable
Z
Local Distribution Choice
Y_{t-1}
Y_{t+1}
Y_T
Q_1
Q_{t-1}
Q_t
Q_{t+1}
Q_T
Markov Chain
W
Local MC Choice

Model equation

$$
\begin{aligned}
W_j &\underset{\text{iid}}{\sim} \mathcal{M}(1, \epsilon), \quad W_j \in \{1, \dots, L\} \\
Z_j &\underset{\text{iid}}{\sim} \mathcal{M}(1, \rho), \quad Z_j \in \{1, \dots, K\} \\
Q_{j,1:T} | W_j &\underset{\text{iid}}{\sim} \text{Markov Chain}(R_{W_j}), \quad Q_{j,t} \in \{1, \dots, q_{max}\} \\
Y_{j,t}^{(1)} | Z_j, Q_{j,t} &\underset{\text{iid}}{\sim} Beta(\gamma_{Z_j}^{(1)}) \text{ truncated on } I(Q_{j,t}) \\
Y_{j,t}^{(2)} | Z_j, Q_{j,t} &\underset{\text{iid}}{\sim} Beta(\gamma_{Z_j}^{(2)}) \text{ truncated on } I(Q_{j,t})
\end{aligned}
\tag{1}
$$

N.B. : $W_j \not\perp Z_j$ and $Y_{j,t}^{(1)} \not\perp Y_{j,t}^{(2)}$

Partition

1d Tercile (as meteorological seasonal prevision)

2d Following $\sim$equi-partition from a gaussian copula with $\rho = 0.5$

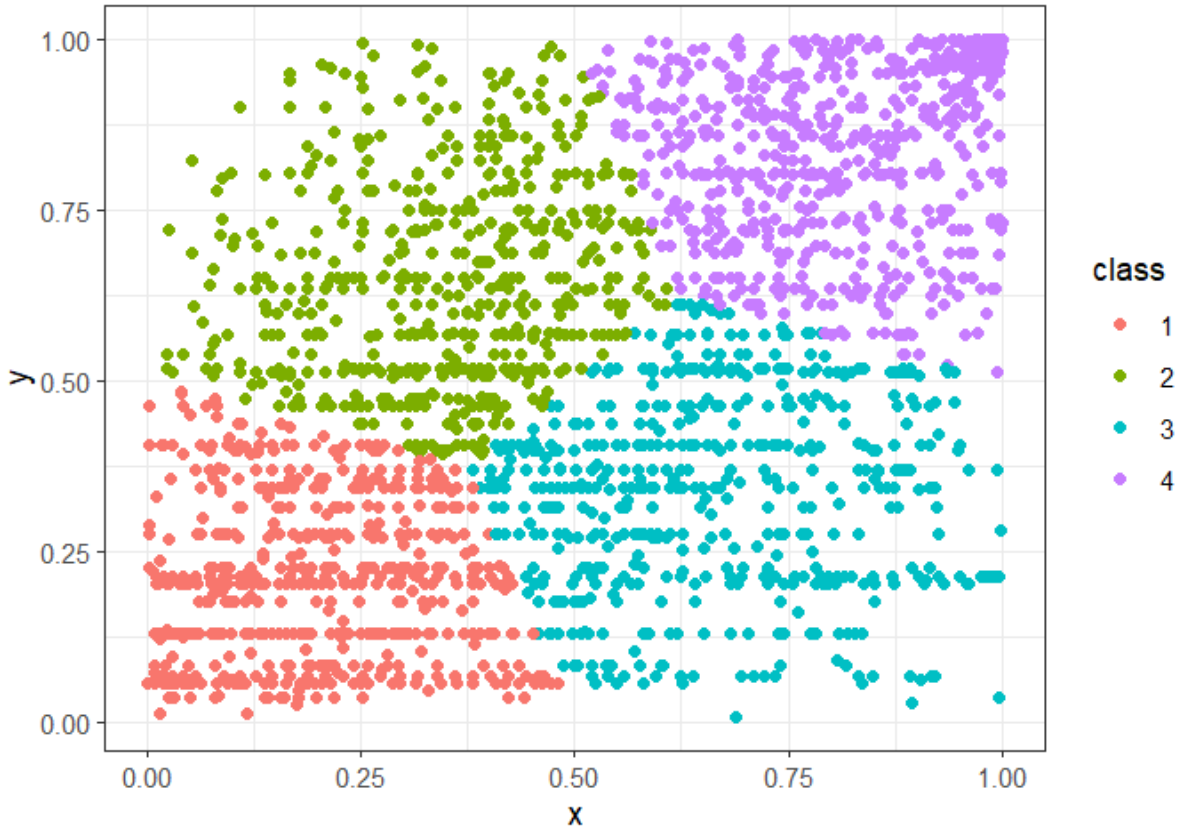


Figure: $\sim$ equi-parition for a gaussian copula with $\rho = 0.5$

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Expectation Maximization Algorithm

E-step :

- Forward - Backward algorithm for each (ZW) pair and each municipality

M-step :

- beta parameters need numerical optimisation that we do with a newton method
- (2d) we simplify the join beta distribution with a "Mean field" approach. [1]

To select number of clusters we use BIC and ICL.

Validation

Principles :

- Sampling with parameters next to our results
- Conserve the same structure of our dataset (missing datas)

Results :

- Good estimation of beta parameters for 3/4 classes
- Good accuracy of Z classification (1d : ~ 0.96) for 3/4 classes
- Limited in the number of class detection
- Not enough data for two periodic Markov chains
- Good estimation of MC parameters with one chain

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Results

- Map of wasting
- Normals estimation by trimesters and municipalities
- Markov chain converge quickly

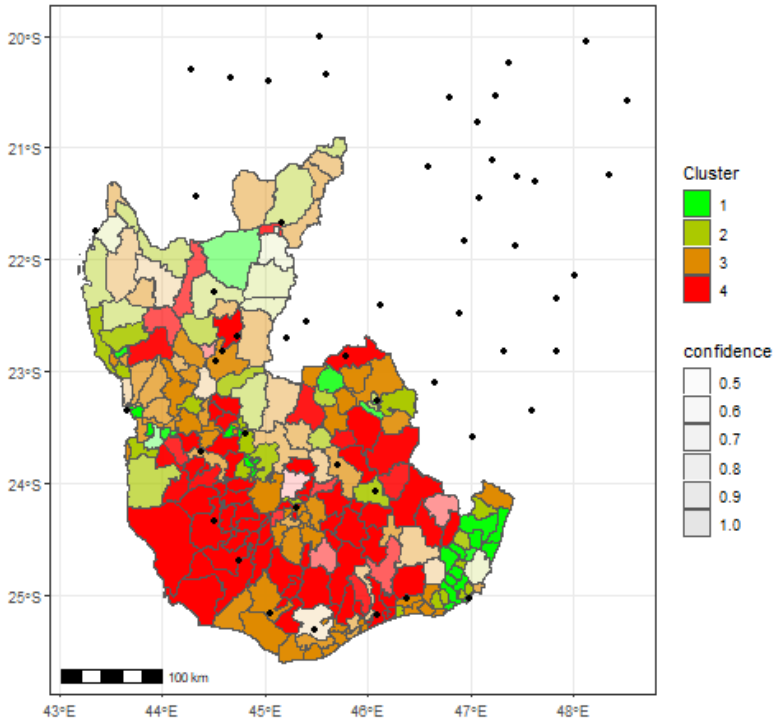

Figure: Wasting clustering map from GAM

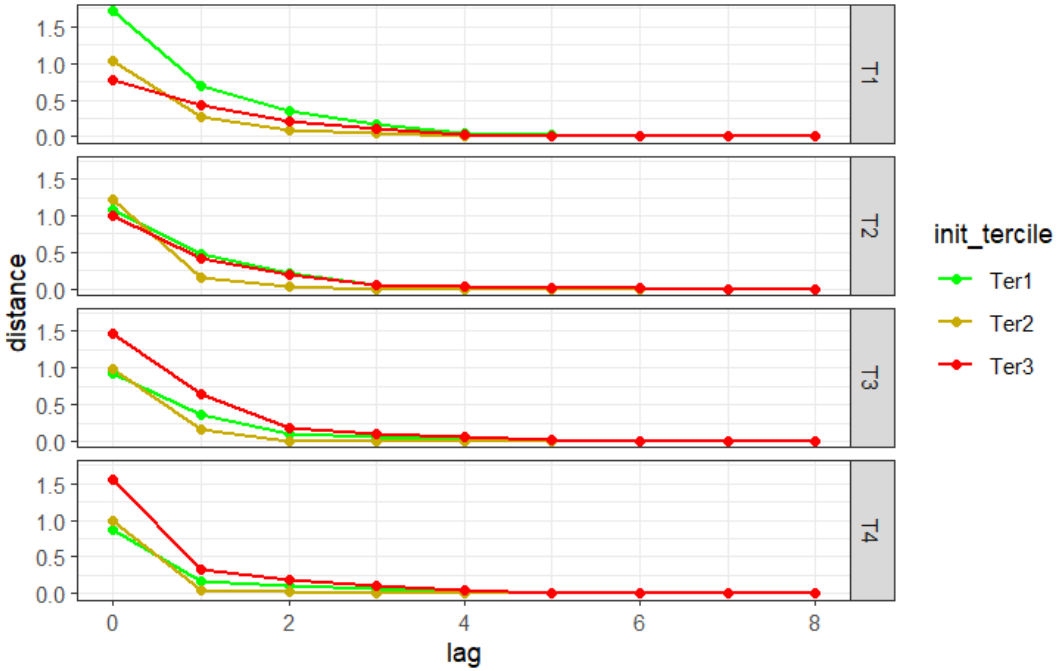

Figure: Evolution of a KL distance of probabilistic prevision based on current observation from normals

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- Relatively unexplored field
- Partners seems to be happy with this first results
- Useful results for more popular models in environmental epidemiology (multi-level regression, distributed lag model)
- Useful step for prevision (*e.g.* provide a reference)
- Which methods to include side datasets (like cluster survey or Nutrition Center admissions) in order to use more operational data, to proceed good fill-in.
- Is there solution to increase number of Periodic Markov Chain