Graduate School@UGA
RISK Thematic program

RISK Summer School 2024

Evolution of the RGA phenomenon under the climate change: awareness, adaptation and prevention

Lamine IGHIL AMEUR (Cerema)

Outline

1. Introduction to the shrinkage-swelling phenomenon (RGA)
2. How the RGA phenomenon evolves under climate change effects since 2015 in France?
3. Information and awareness on the RGA consequences
4. Does prevention allow to reduce RGA vulnerabilities?
5. New approaches and innovative RGA projects for the adaptation

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1. Introduction to the shrinkage-swelling phenomenon (RGA)

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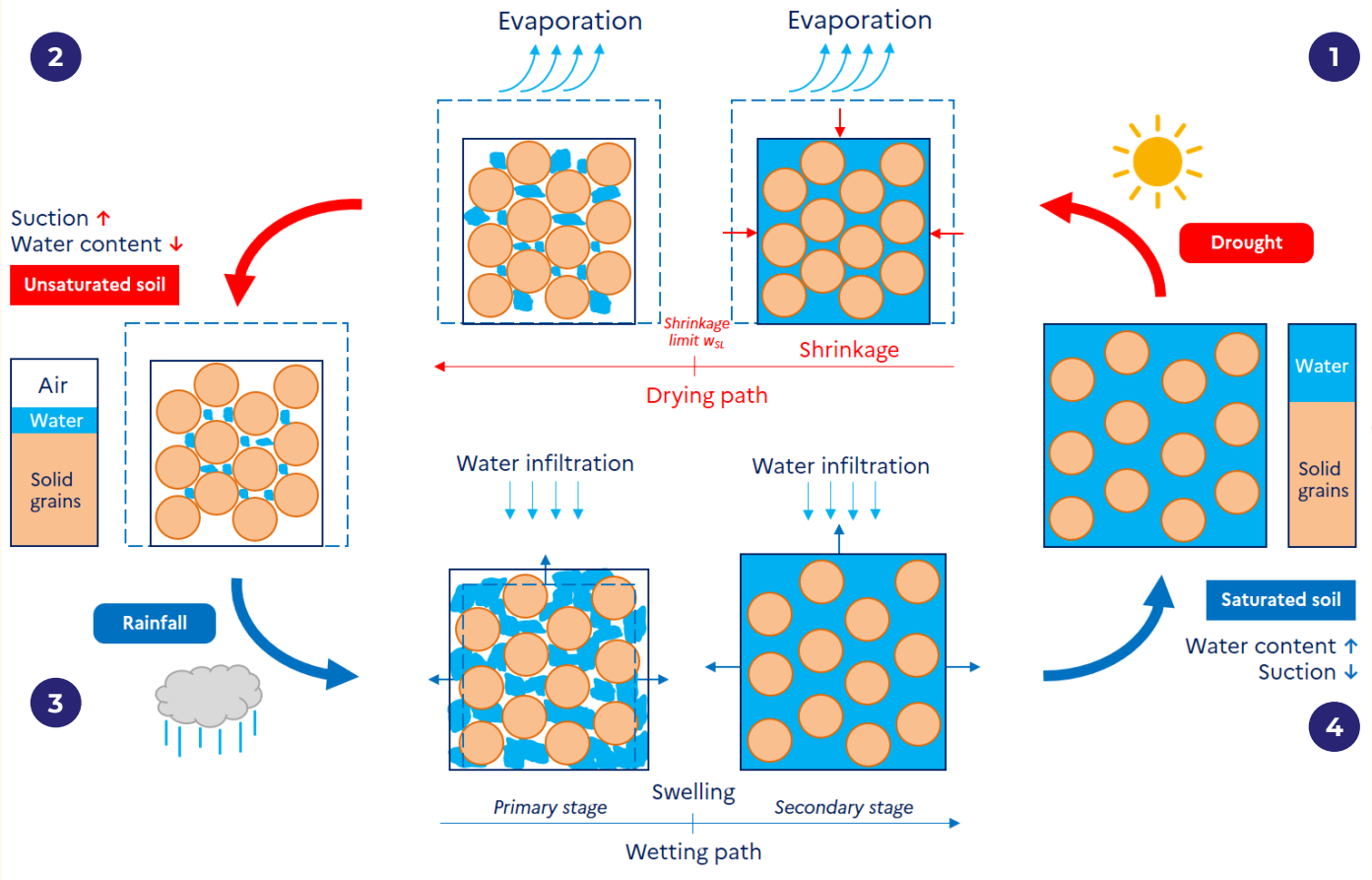
On this drying path, the water content of the soil decreases and conversely, the suction increases and the soil becomes unsaturated in the final state

Soil suction which can be influenced by meteorological conditions and those of the close environment, is likely to affect the kinetics of shrinkage under the effect of drought

On the path of humidification by water infiltration (rainfall), the soil undergoes the phenomenon of swelling in two stages (Reiffsteck, 1999)



Ighil Ameur (2023)

An "idealized" element of a saturated soil subjected to a drying path (drought) records both a volume deformation (red arrows) in the direction of shrinkage and a loss of mass related to the evaporation of the water present in the soil

The natural processes of shrinkage and swelling are a succession of variations in the water content of a clay soil under the effect of hydric and cyclic solicitations influenced by the meteorological conditions of drought and rainfall

On this wetting path, the water content of the soil increases and conversely, the suction decreases and tends towards zero when the soil becomes saturated in the final state at the end of the complete drying-wetting cycle

1. Introduction to the shrinkage-swelling phenomenon (RGA)

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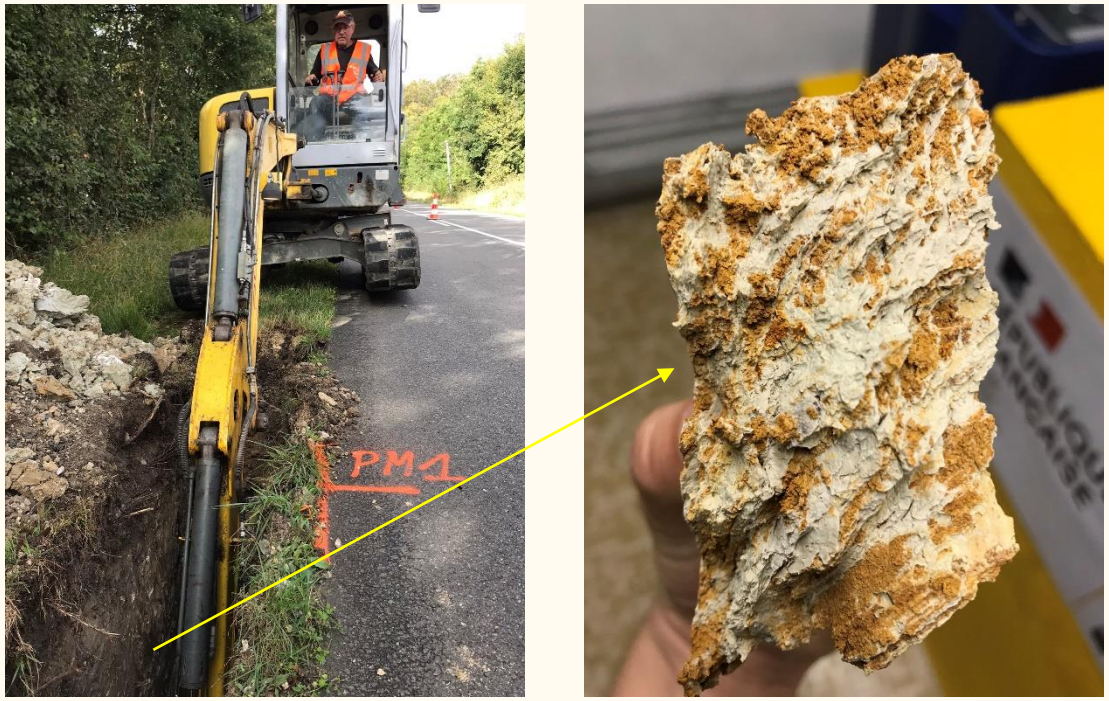
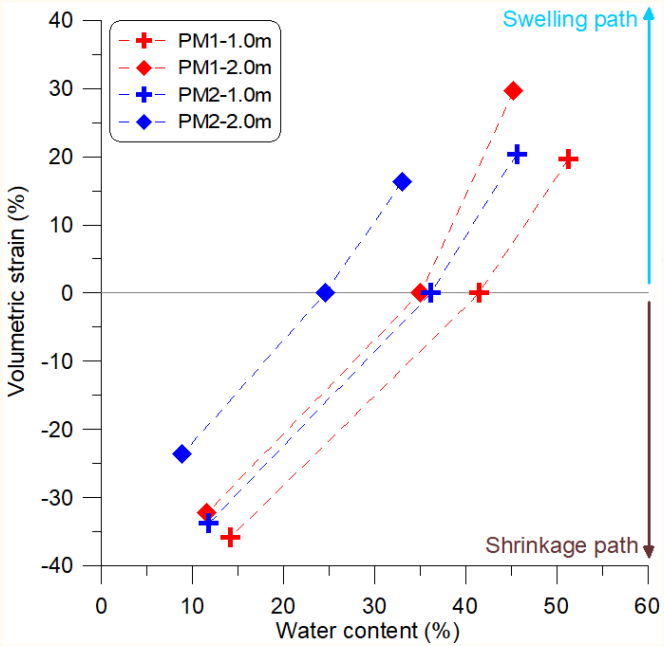
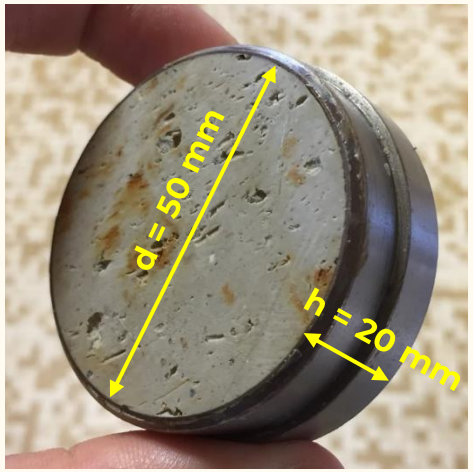
- Tested clay soil collected in situ using a mechanical shovel



- Volumetric strain during shrinkage and swelling tests





ME81 according to the Australian standard AS 1289.7.1-2003

Ighil Ameur (2023)

1. Introduction to the shrinkage-swelling phenomenon (RGA)

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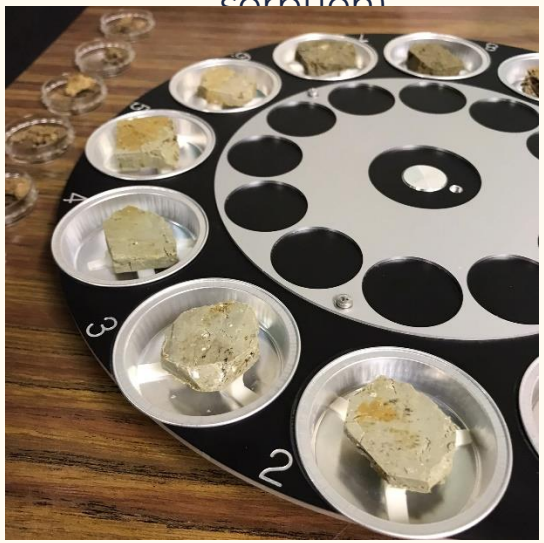
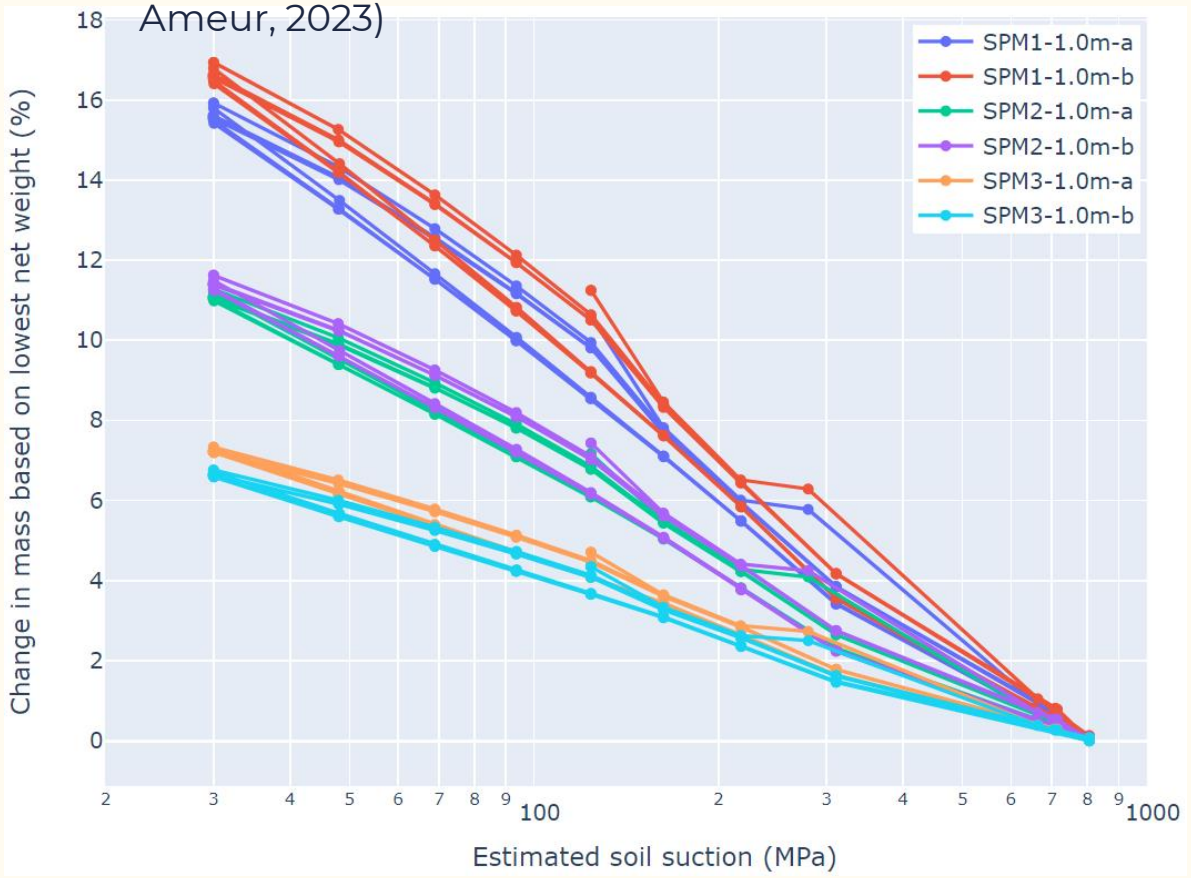
- Example of a DVS test (dynamic vapor sorption)



Hydric paths	Imposed RH (%)	Duration (hours)	Cycles
Preconditioning	40.0	48.0	
Drying path	40.0 to 0.0	108.5	
Plateau	0.0	48.0	Cycle repeated 3 times
Wetting path	0.0 to 80.0	184.0	
Plateau	80.0	48.0	
Drying path	80.0 to 0.0	195.0	
Plateau	0.0	48.0	

- Change in mass as a function of soil suction during the DVS test (Ighil Ameur, 2023)



Fredlund and Rahardjo (1993):

$$s = -\frac{\rho_w RT}{M_w} \ln\left(\frac{HR\%}{100}\right)$$

2. How the RGA phenomenon evolves under climate change effects since 2015 in France?

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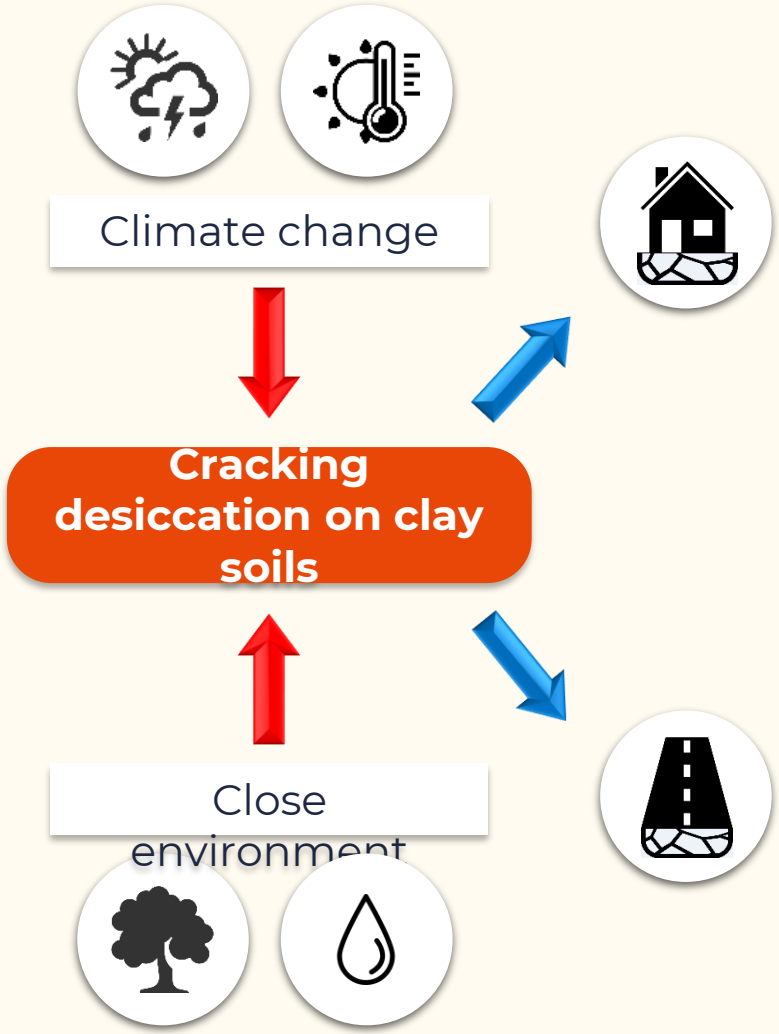
Climate change effects: some observations

- Since 2015, severe and recurrent droughts during a long period sometimes including the winter season
- Recurrent heatwaves and disrupted seasonality
- Since 2022, cracks and damages of infrastructures have a tendancy to appear quickly during the drought period
- Drought insured damage increases yearly and becomes the first insured natural hazard in France



2. How the RGA phenomenon evolves under climate change effects since 2015 in France?

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Post-2015 highlights:

- Drought expansion impacts other infrastructures
- Geographical extension of the RGA phenomenon in terms of exposure
- More than one in two houses is highly exposed to the RGA
- Drought becomes the costliest natural hazard these last 10 years
- Drought gradually spreads across the whole of France
- Soil desiccation propagates deeper (more than 3 m)
- An exceptional drought in 2022

Bike lanes

Earthworks

Railways

2. How the RGA phenomenon evolves under climate change effects since 2015 in France?

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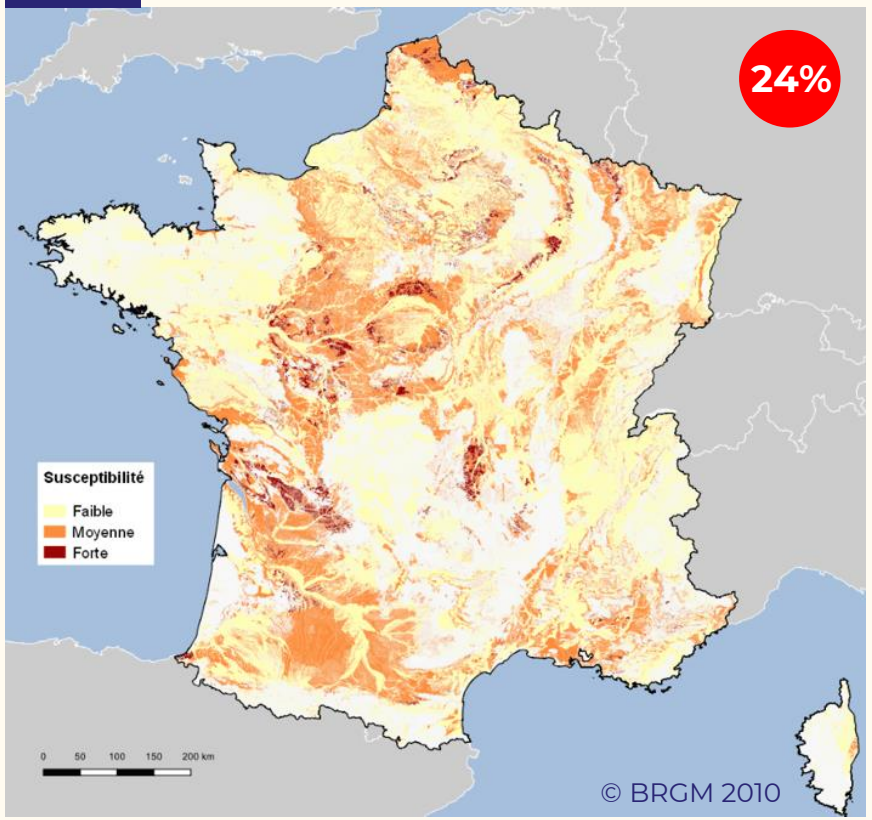
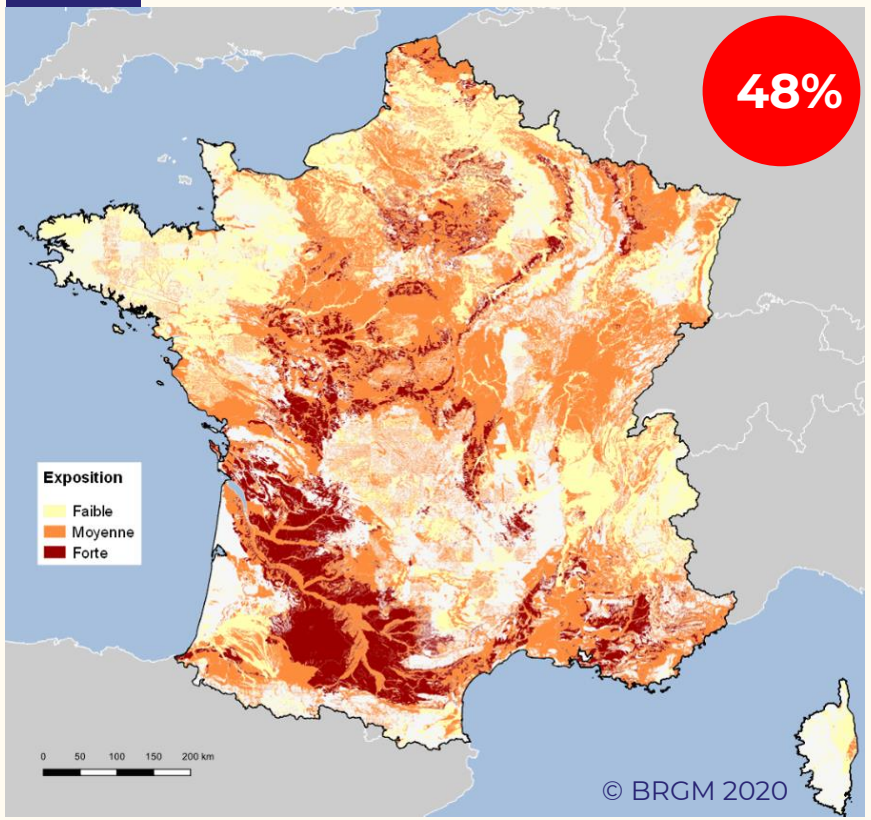
- Geographical extension of the RGA phenomenon in terms of exposure

2010



2020



2. How the RGA phenomenon evolves under climate change effects since 2015 in France?

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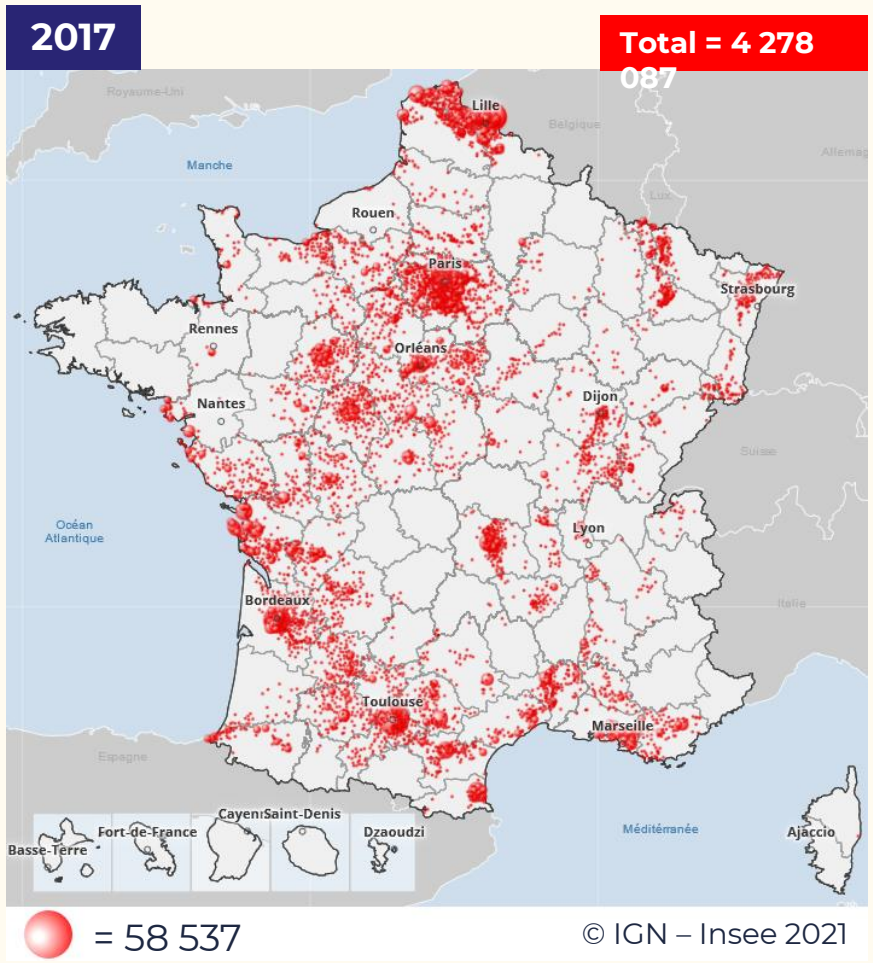
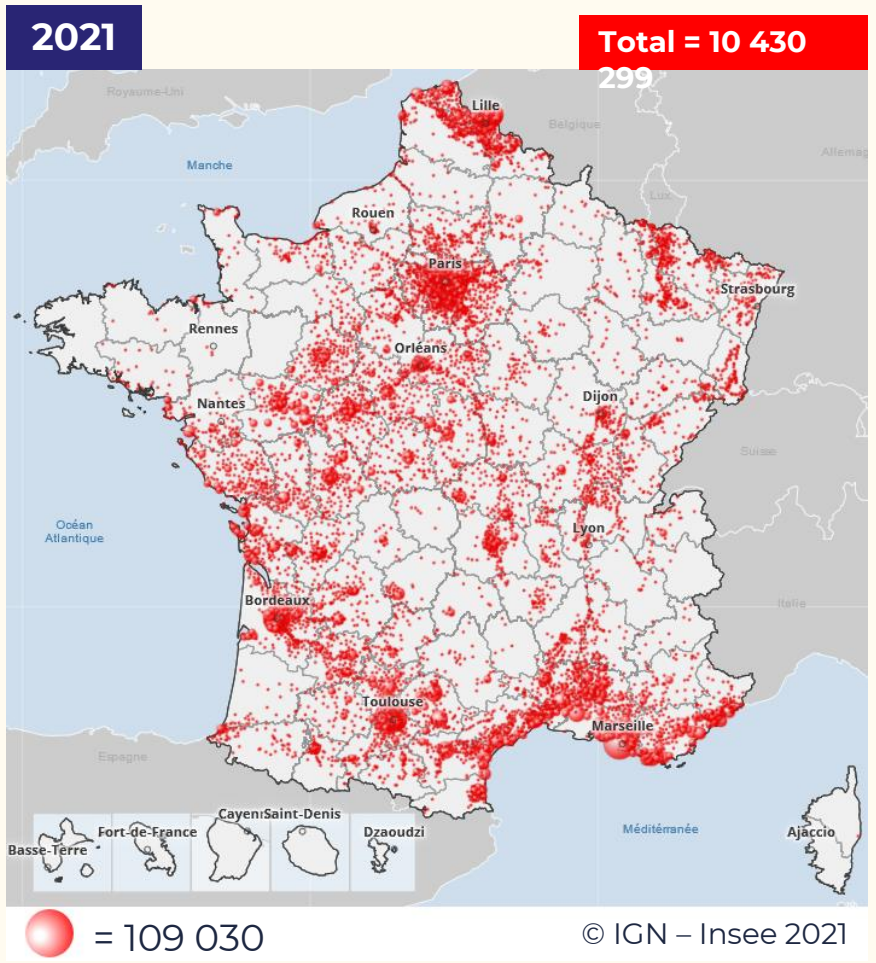
➔ More than one million houses is highly exposed to the RGA



High or moderate



Data source : ONRN 2014 (MàJ 2016)

Data source : SDES 2021

2. How the RGA phenomenon evolves under climate change effects since 2015 in France?

- Drought becomes the costliest natural hazard these last 10 years

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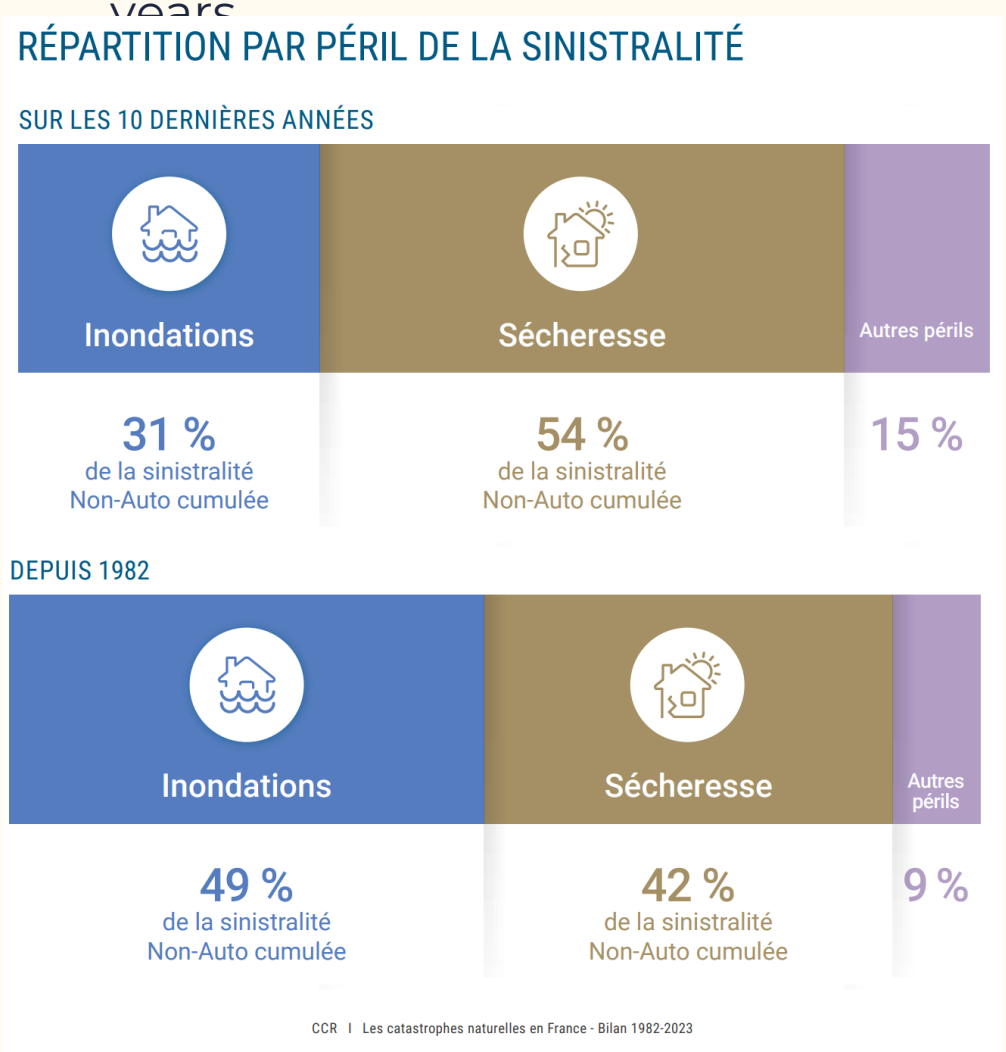
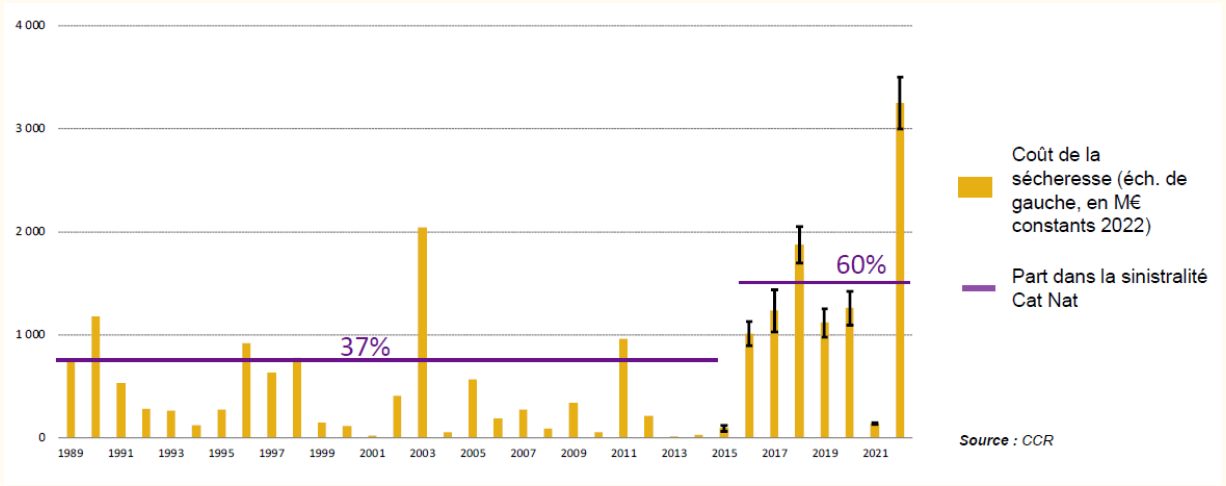
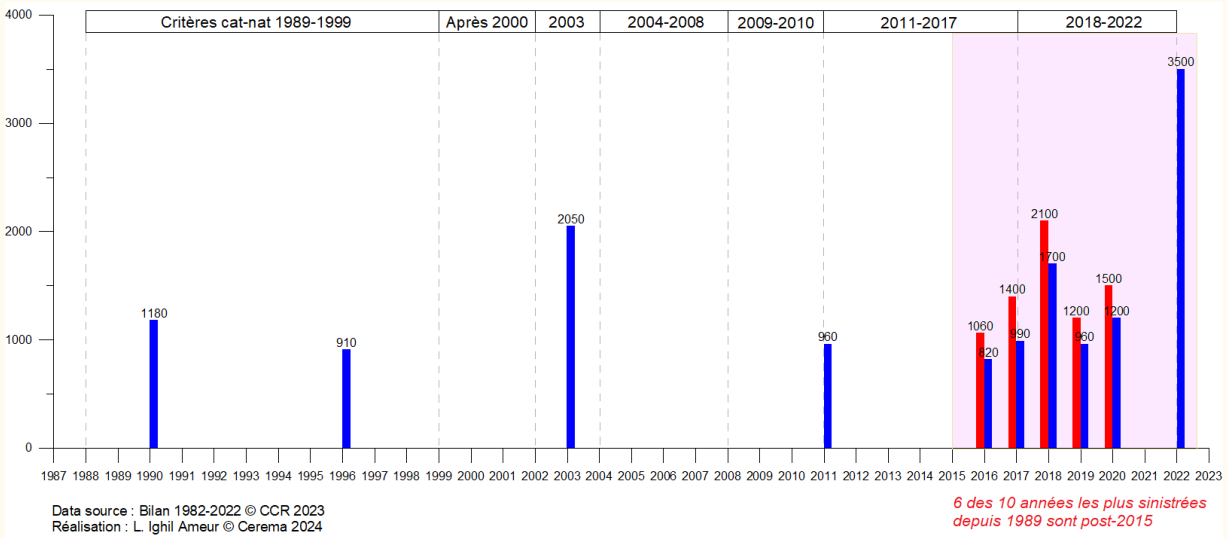
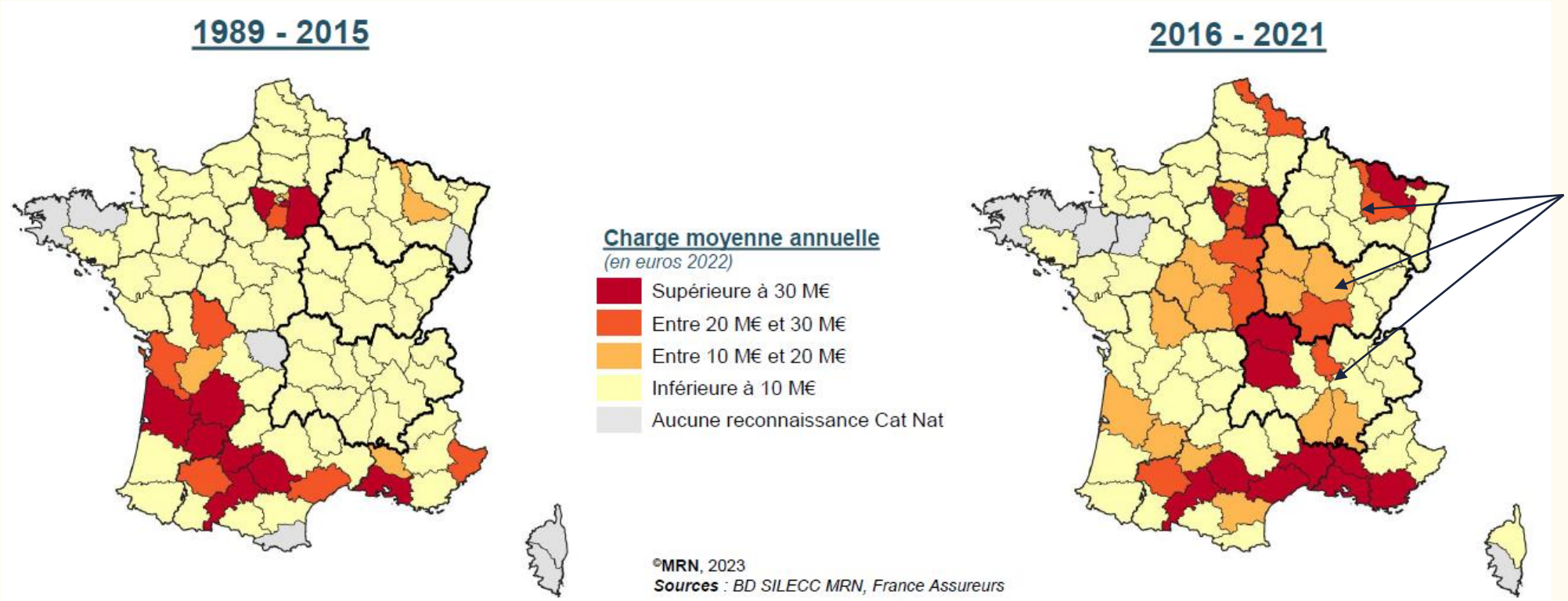






2. How the RGA phenomenon evolves under climate change effects since 2015 in France?

- Drought gradually spreads across the whole of France



On average since 2016, in these three regions, average annual charges have increased tenfold

Comparison of average annual charges by department before and since 2016 (© MRN 2023)

2. How the RGA phenomenon evolves under climate change effects since 2015 in France?

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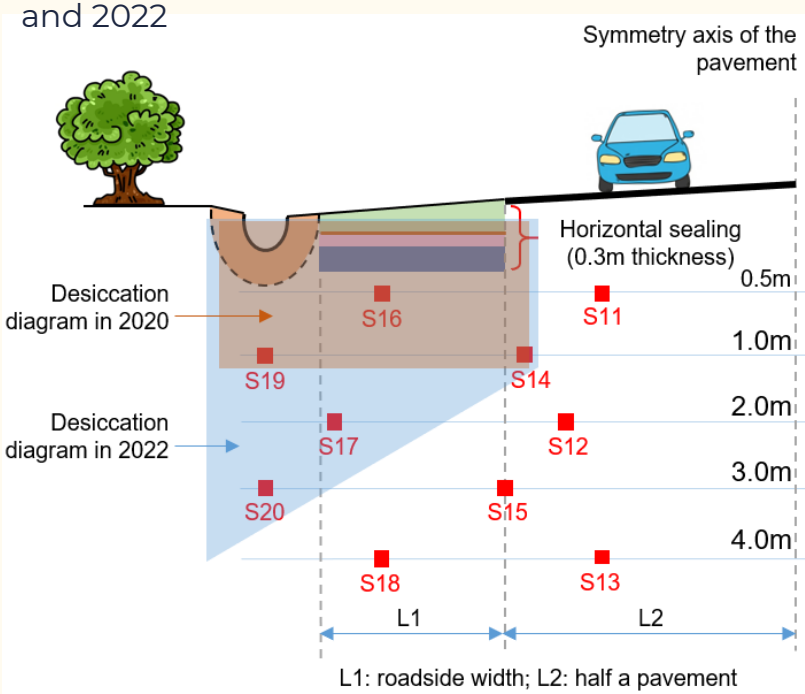
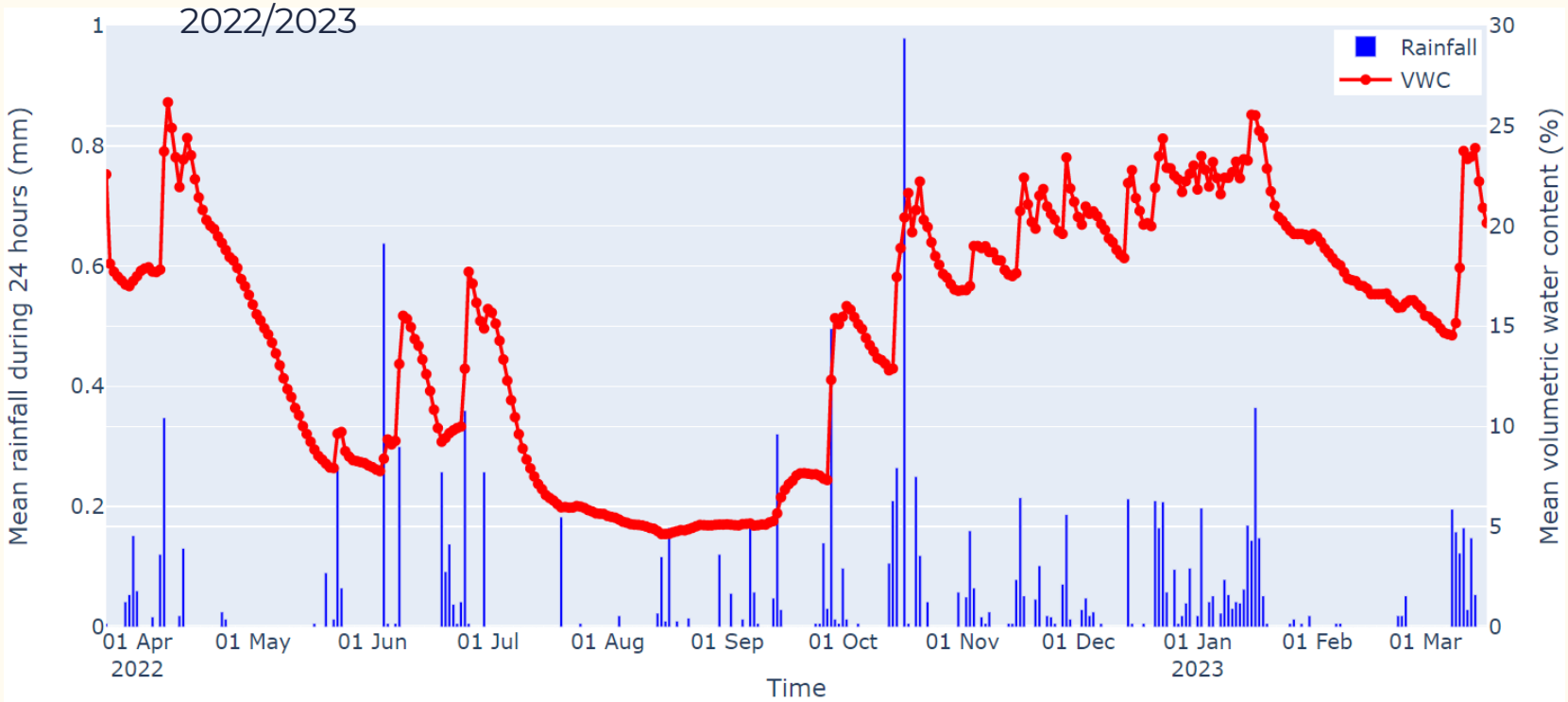
- Soil desiccation propagates deeper (more than 3 m)

Desiccation propagation diagram between 2020 and 2022



Mean rainfall and volumetric water content change as a function of time in 2022/2023



- *Soil desiccation was developed essentially under the roadside until 1.0m depth in 2020 but it propagated more until 3.0m depth in 2022*

- *2022 drought is severe with a very low levels of rainfall and VWC=5% from July to October*

- *During 32 consecutive days in 2023 winter (January to March), it was an impressive drought without precipitation and a VWC gap of 15% which habitually observed in April/May*

Ighil Ameur (2023)

2. How the RGA phenomenon evolves under climate change effects since 2015 in France?

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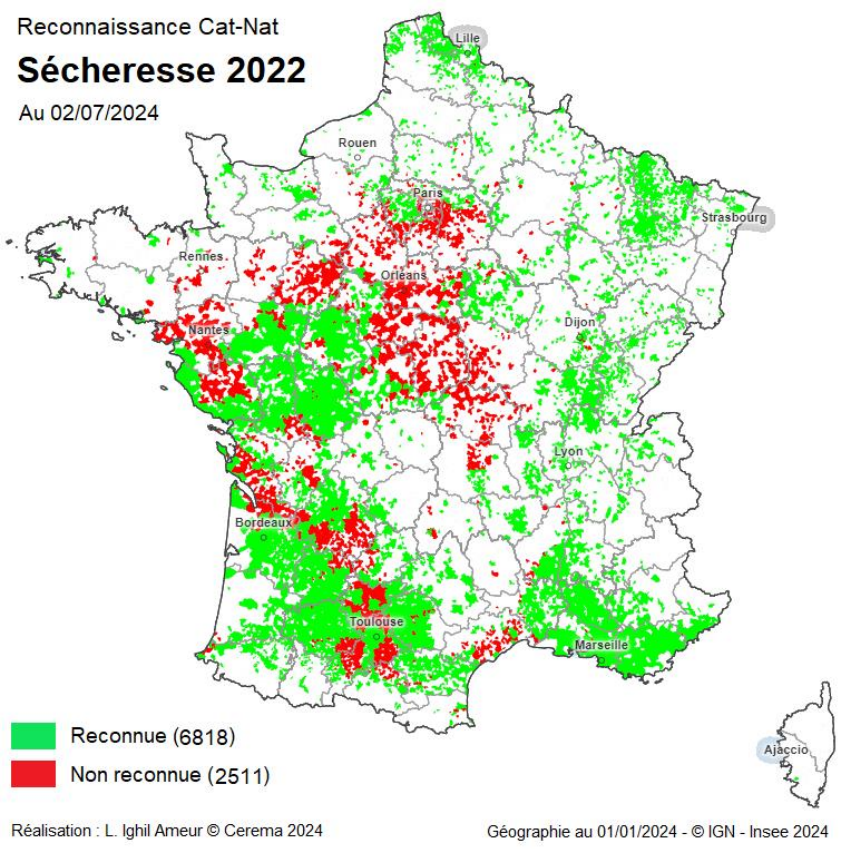
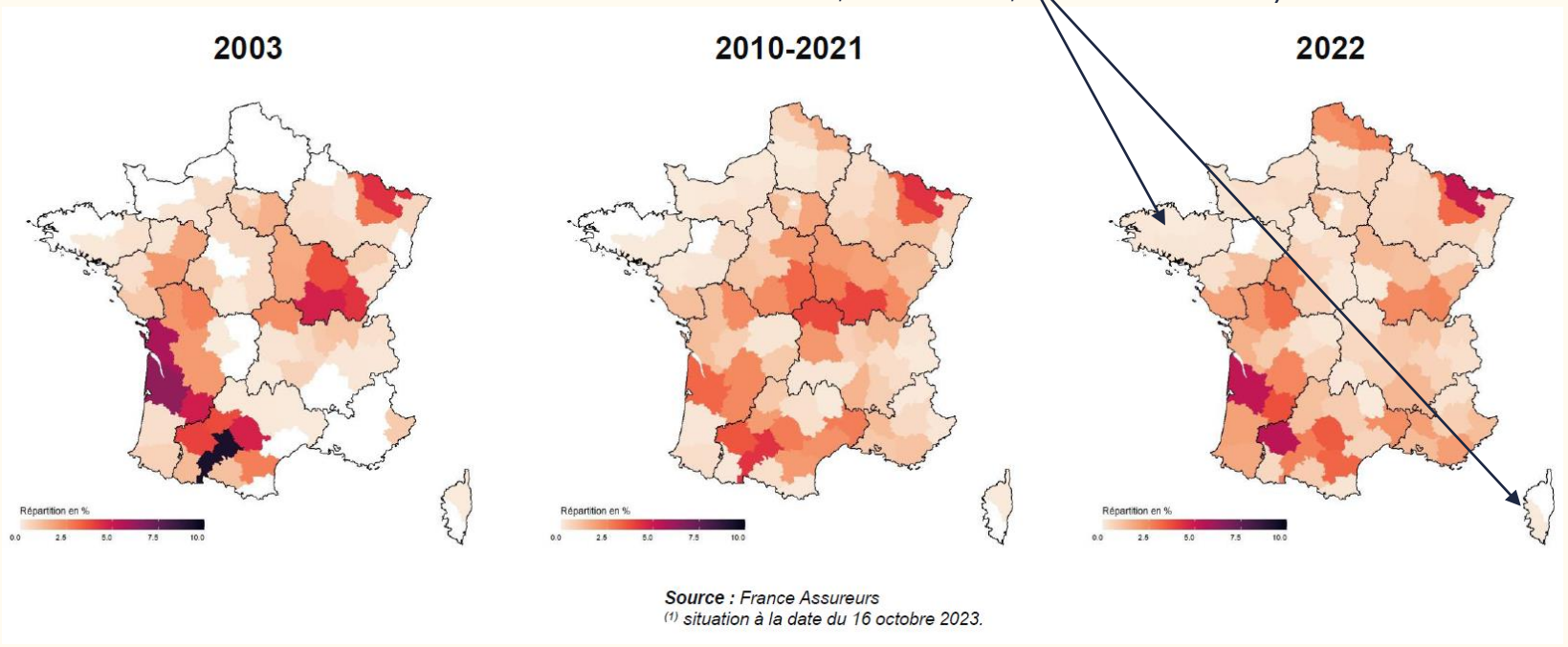
An exceptional drought in 2022



Map of recognized and unrecognized municipalities Cat-Nat drought 2022 (© Cerema 2024)

In 2022, drought affected almost the entire metropolitan territory: 92 departments including 3 for the first time in history (Côtes d'Armor, Finistère, South Corsica)



Distribution of drought Cat-Nat decrees (© France Assureurs 2023)

3. Information and awareness on the RGA consequences

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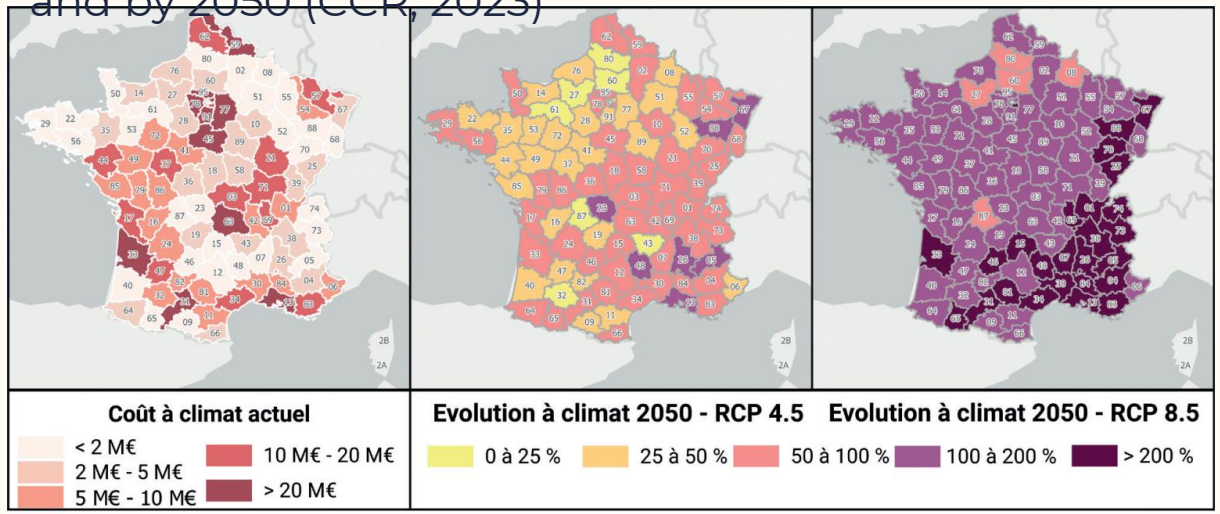
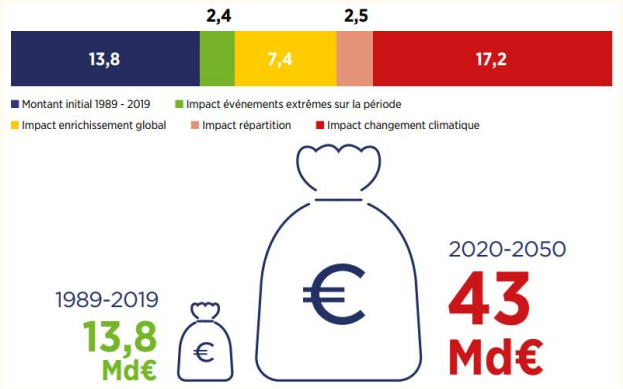
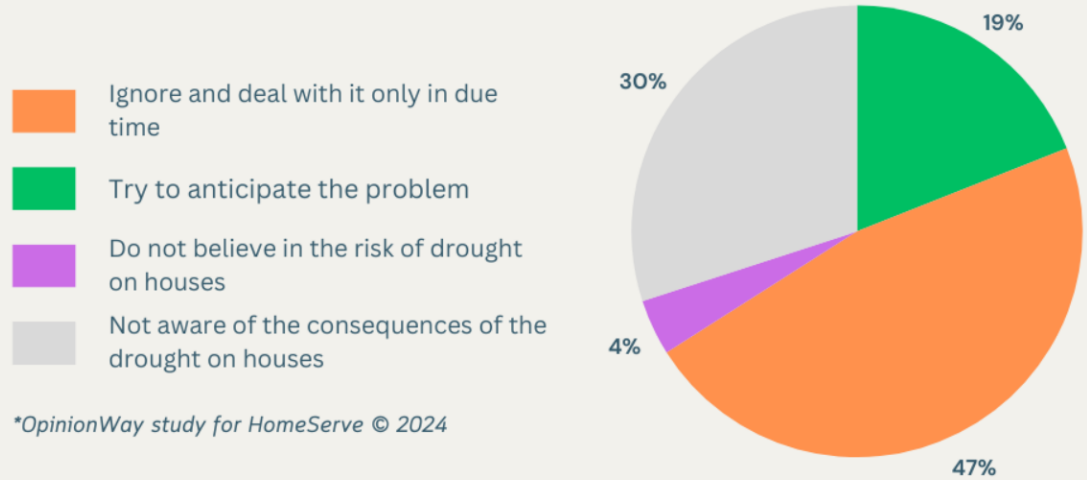
- Distribution of average annual costs due to drought by department in metropolitan France with current climate and by 2050 (CCR, 2023)





DÆGÊ3 ÇÎHIHŠ3IHÎÃÃÀÀÃÁ

DROUGHT, RGA AND CRACKS: WHAT DO THE HOUSE OWNERS THINK?



OpinionWay study for HomeServe © 2024

3. Information and awareness on the RGA consequences

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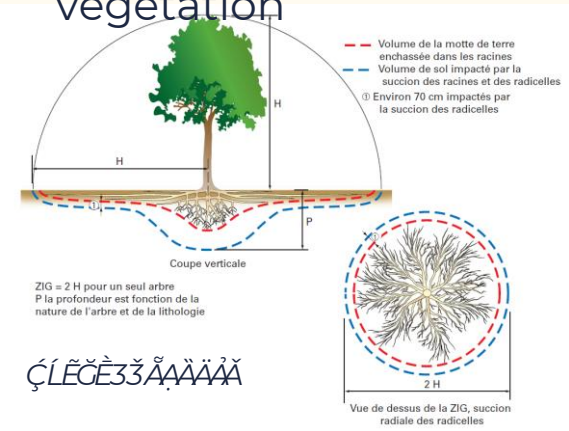
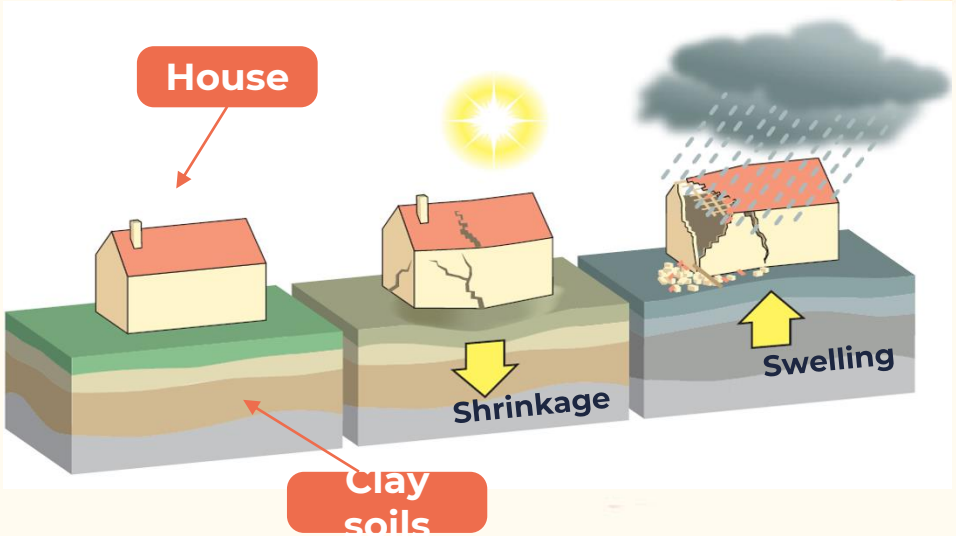
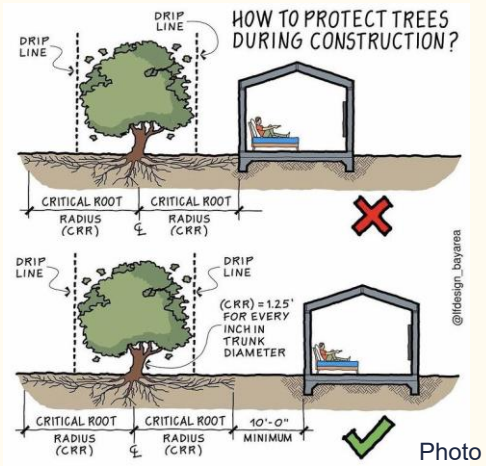
- Influence of the vegetation







Vegetation is not a problem when planted at an adequate distance to avoid increasing soil suction by the roots

Photo credit: Luis Furushio © LF Design

- Influence of the water cycle

The drainage around the construction must be up to standards and reliable to avoid unwanted infiltration that could cause the foundations to collapse

Photo credit: Luis Furushio © LF Design

3. Information and awareness on the RGA consequences

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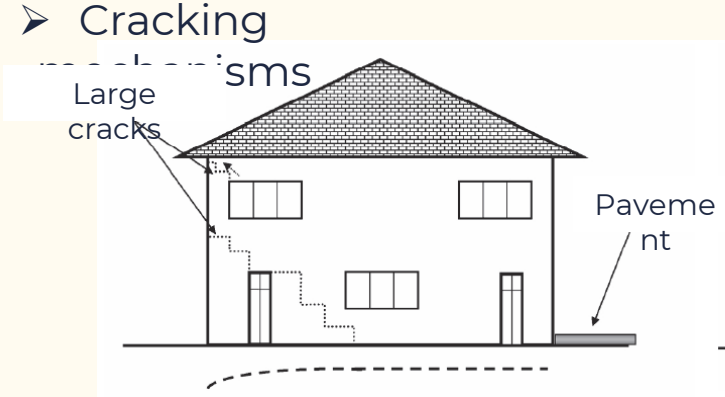
- Origins of structural damage due to the drought and example of consequences on individual houses (Ifsttar et Ineris, 2017)

- Inadequate rainwater evacuation system

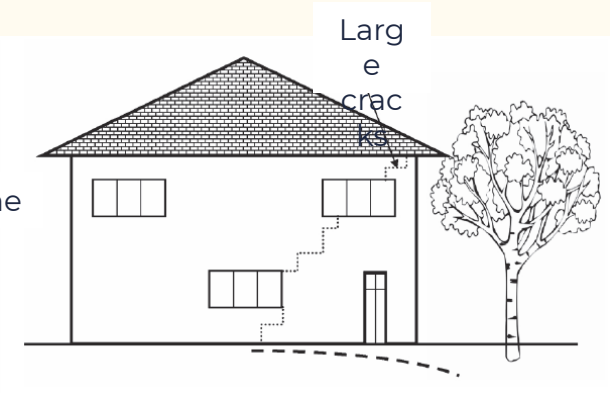
- Influence of the vegetation

- Construction defects

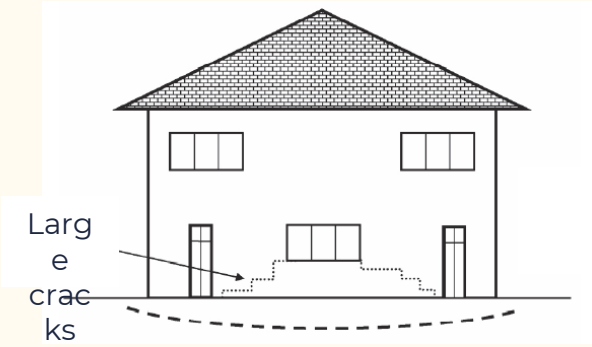
- Cracking mechanisms



Deformation mode caused by peripheral shrinkage of the soil under the house



Deformation mode caused by localized shrinkage of the soil due to influence of trees



Deformation mode caused by settlement of a facade wall

3. Information and awareness on the RGA consequences

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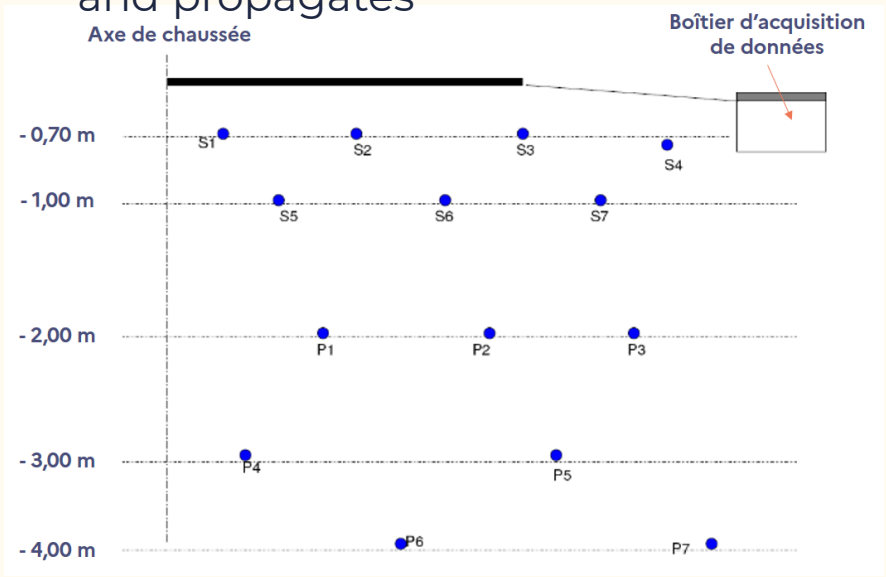
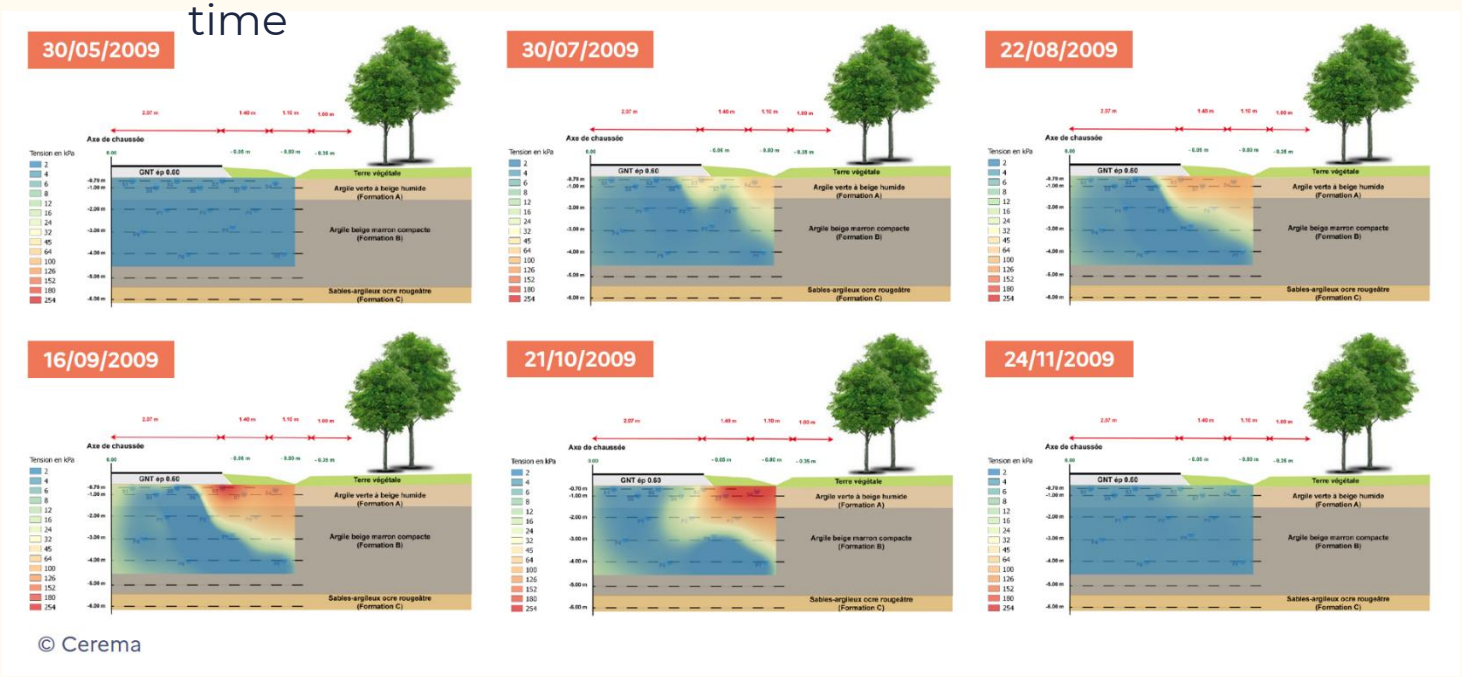
- Example of field monitoring of a road to understand how soil desiccation initiates and propagates



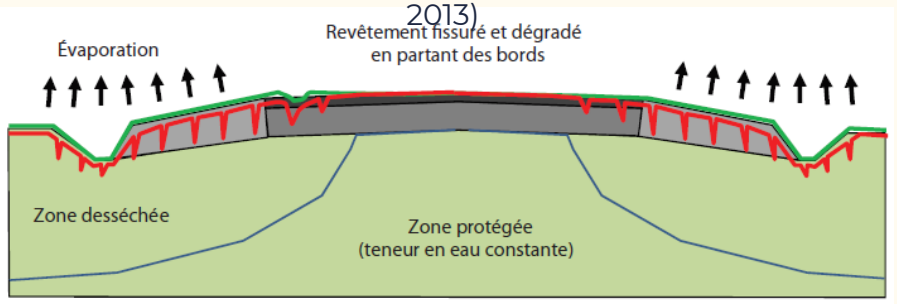
Watermark® probes

Monitor® data logger

- Suction evolution maps as a function of time



Damage mechanisms of a road exposed to the RGA phenomenon (Magnan, 2013)



3. Information and awareness on the RGA consequences

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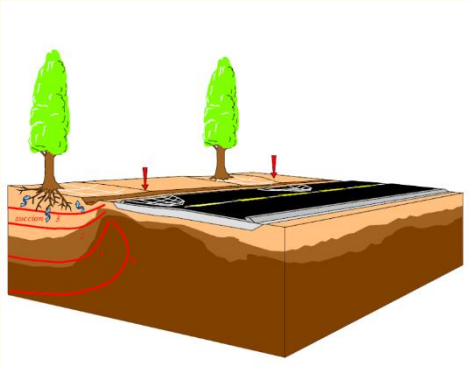
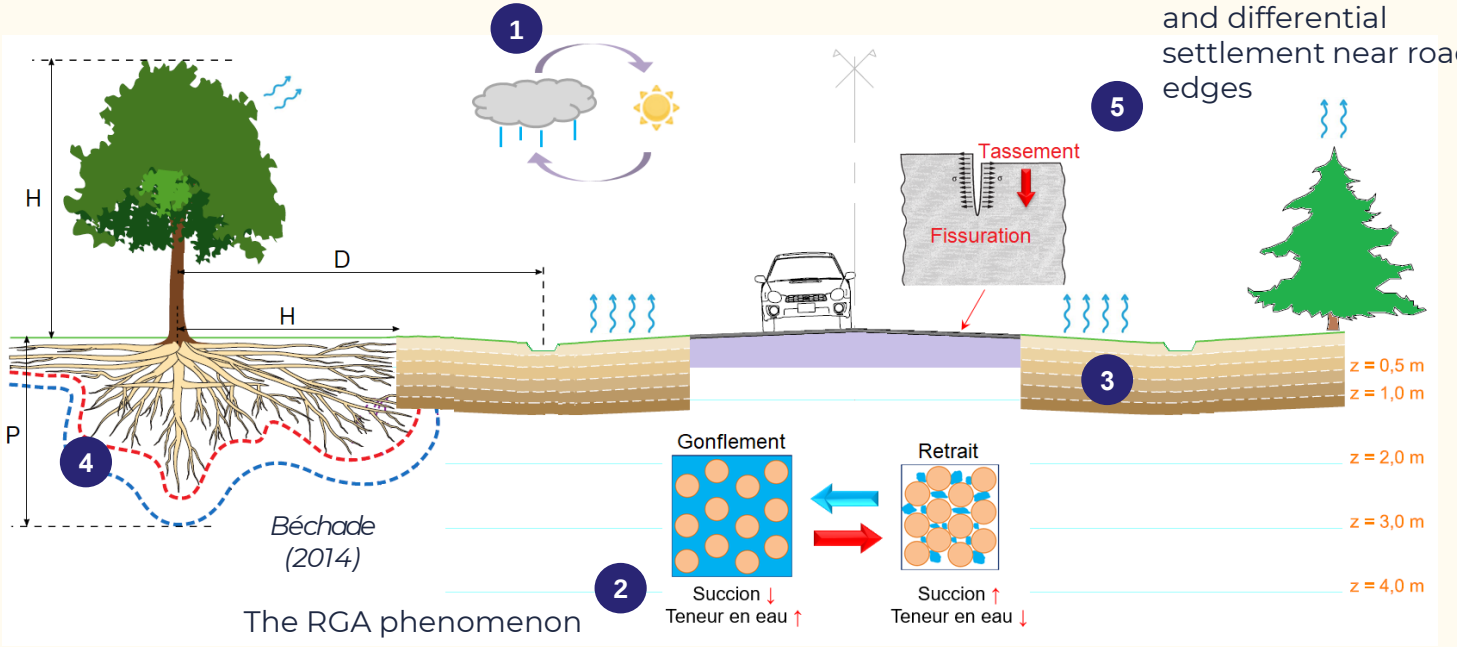
- How the RGA phenomenon impacts the road in its close environment?



Increased suction generated in the zone of the roots influence of the vegetation bordering the road

Drying-wetting cycles (droughts increasingly accentuated by the effects of climate change)

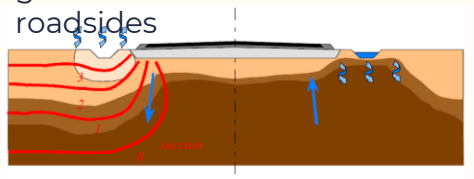


Béchade (2014)

The RGA phenomenon

Longitudinal cracking and differential settlement near road edges

Desiccation waves during a drought episode at ground level under roadsides



Reiffsteck (1999)

4. Does prevention allow to reduce RGA vulnerabilities? Yes, earlier as possible!

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2015

2016

2017

2018

2019

2019

202 0

202 0

4. Does prevention allow to reduce RGA vulnerabilities? Yes, earlier as possible!

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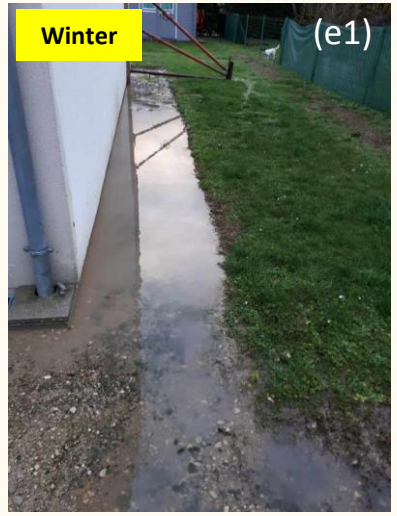

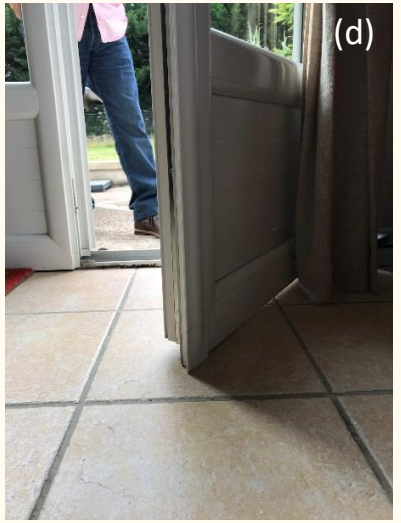

4. Does prevention allow to reduce RGA vulnerabilities? Yes, earlier as possible!

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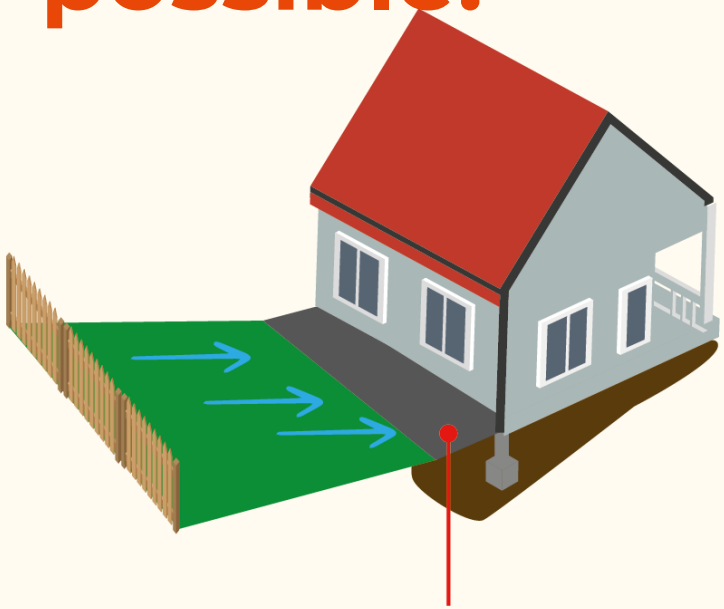
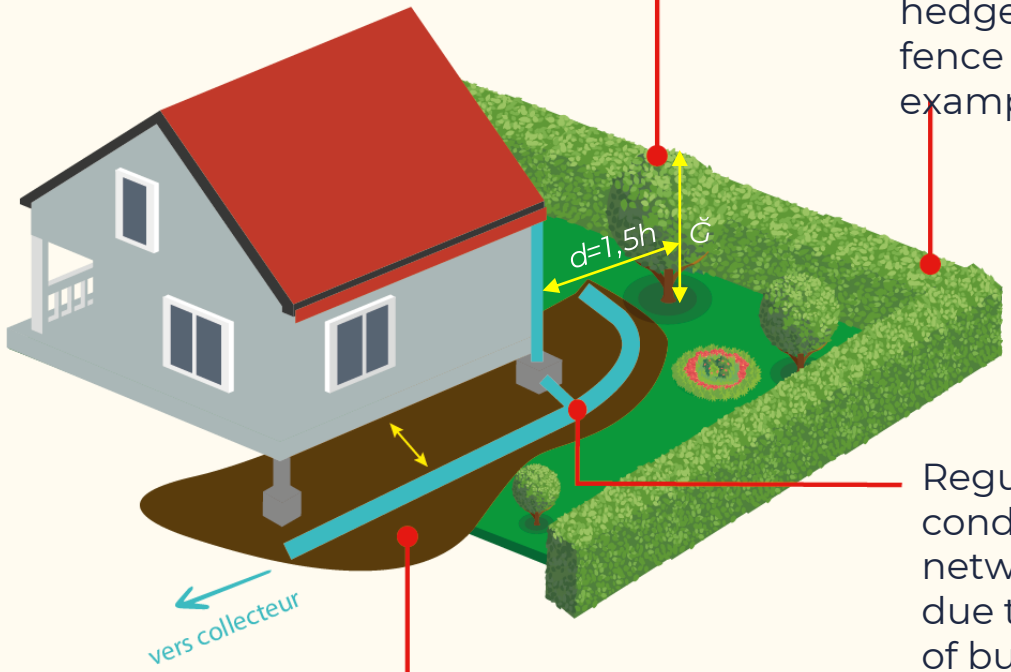


When faced with sloping ground and exposed bare perimeter, apply the necessary recommendations for peripheral horizontal waterproofing and adequate water drainage

If possible, keep all vegetation (trees, shrubs, hedges, etc.) away from the facades (as a guide, the recommended distance is d = 1.5 times the height of the vegetation at maturity)

If possible, replace the hedge with a non-vegetal fence (metal or wood for example)



Regularly check the condition of the sanitation networks to prevent leaks due to the possible cracking of buried pipes by the RGA

If possible, as a precaution, move buried networks away from the facades to avoid, in the event of leaks, any impact on the foundations while waiting for the damaged pipes to be renovated

5. New approaches and innovative RGA projects for the adaptation

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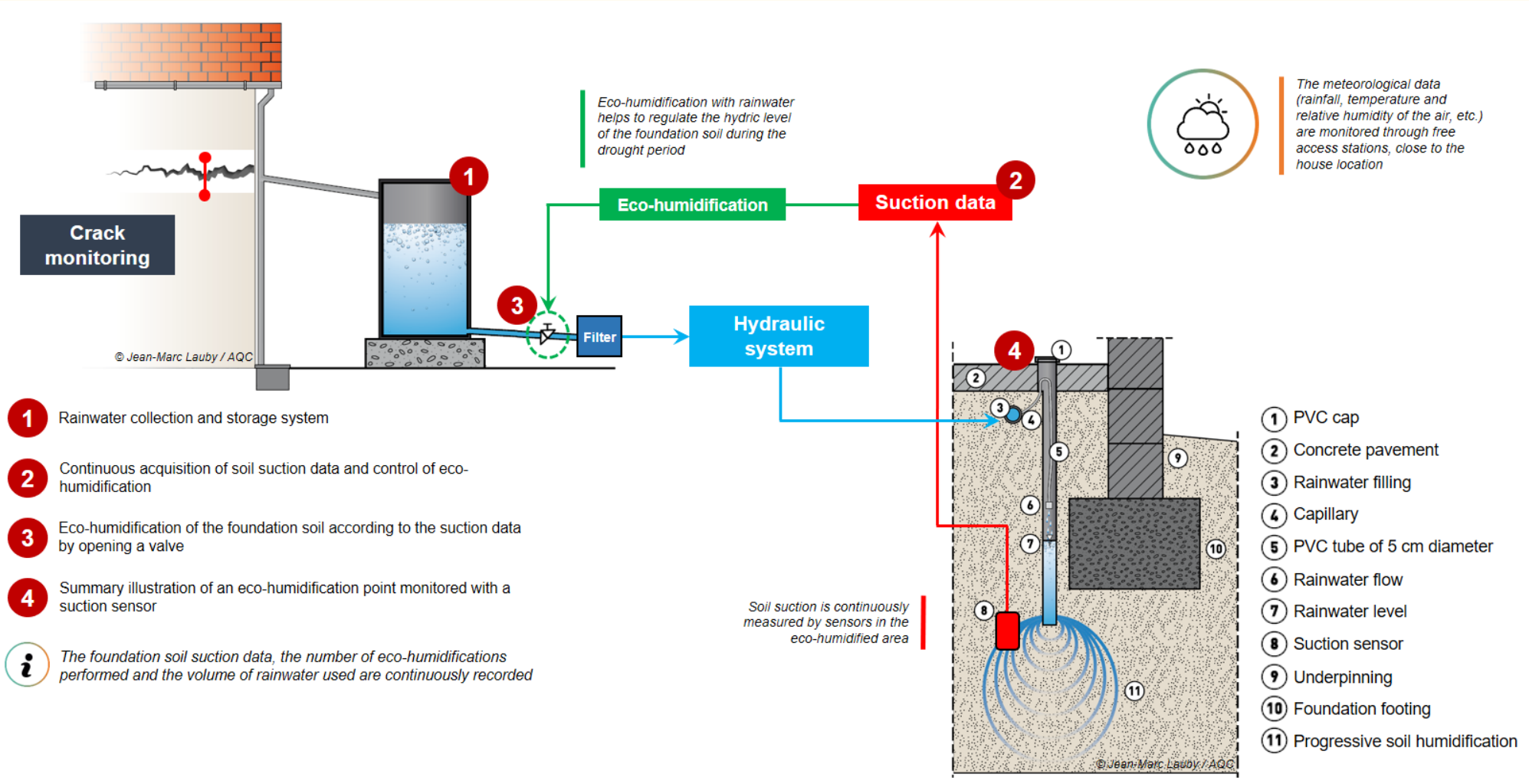
➢ The MACH solution « MAison Confortée par Humidification » developed by Cerema



5. New approaches and innovative RGA projects for the adaptation

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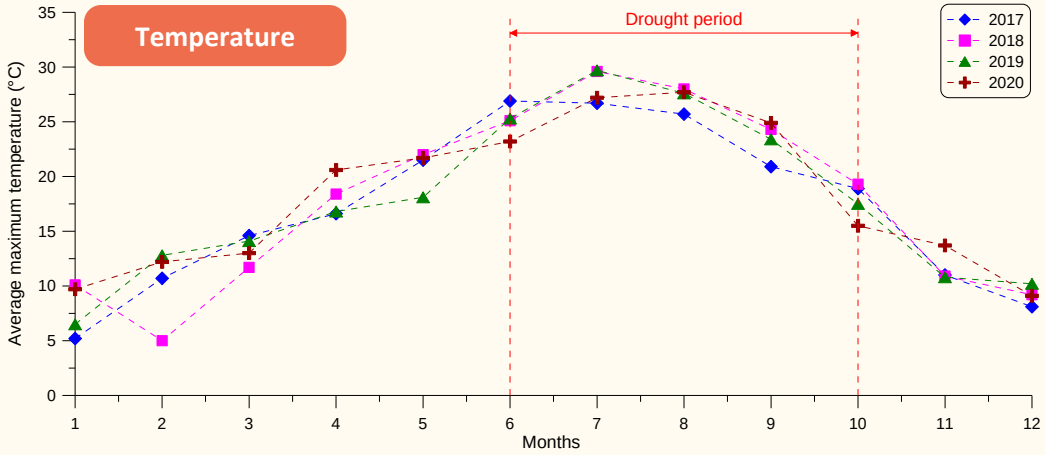
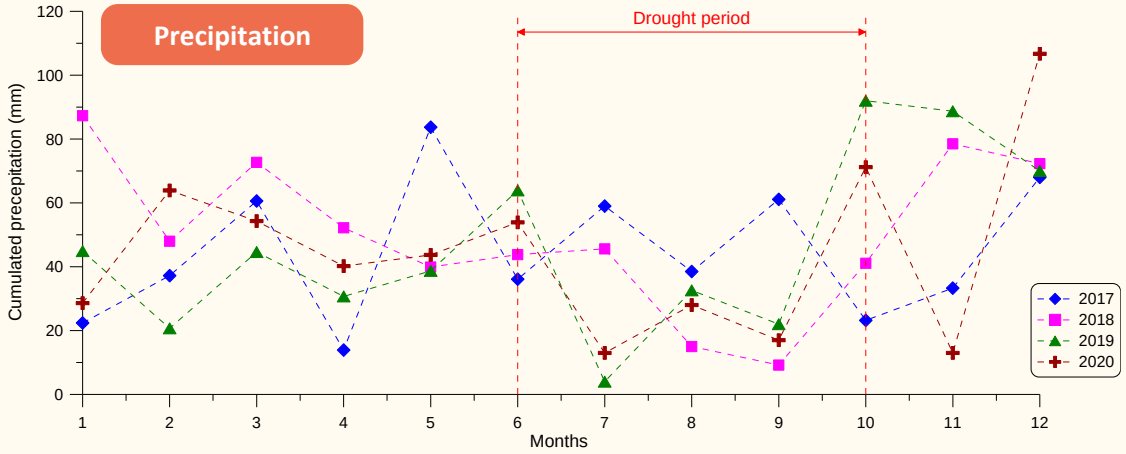
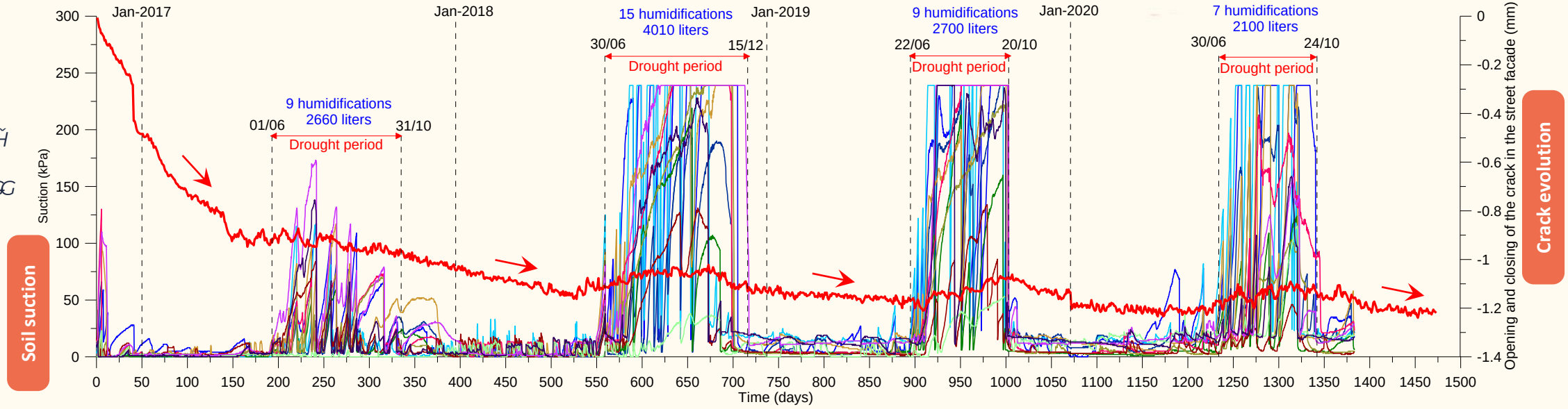
➢ The MACH solution « MAison Confortée par Humidification » developed by Cerema

Meteorological parameters evolution during 4 years at the MACH site in terms of temperature and precipitation







Crack closure

5. New approaches and innovative RGA projects for the adaptation

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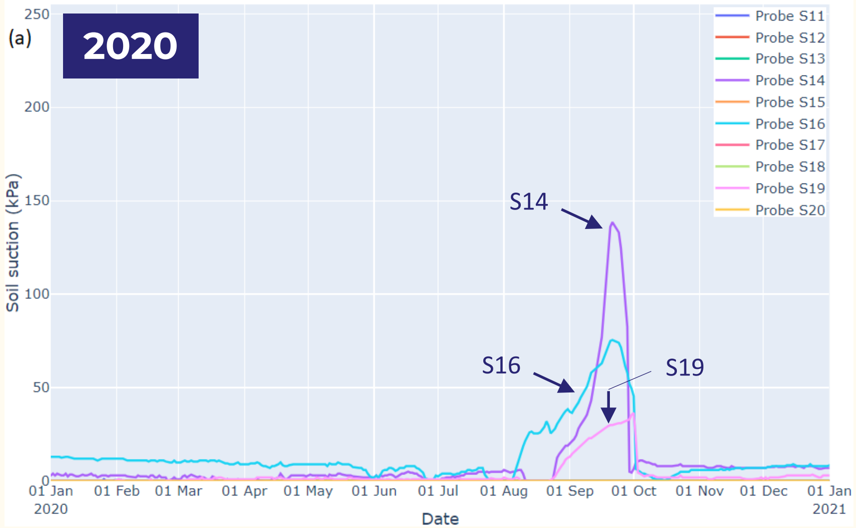
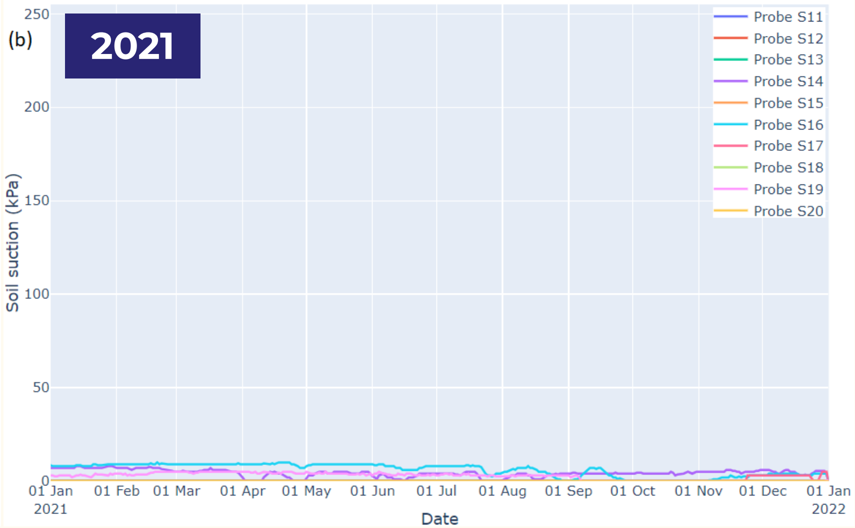
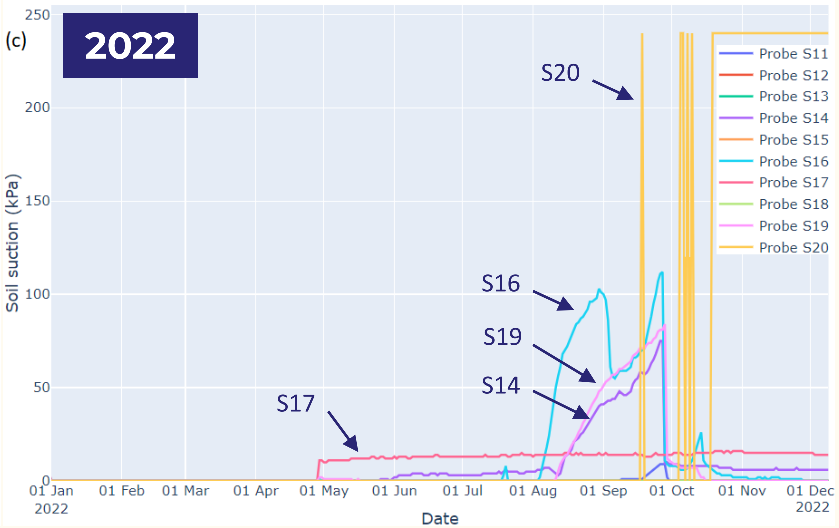
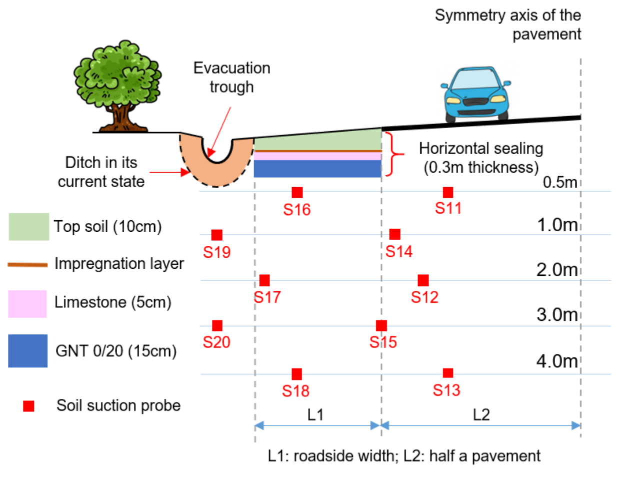
➢ The horizontal sealing of road shoulders technique developed by Cerema









Ighil Ameur (2023)

11/18/2020

12/03/2021

12/09/2022

✓ [illegible]

✓ [illegible]

5. New approaches and innovative RGA projects for the adaptation

RISK Summer School 2024

***S**urveillance **E**tendue du niveau d'**H**umidité des **S**ols argileux pour l'**A**daptation et la **R**ésilience du bâti face au changement climatique*

Objectif du projet

- Le projet **SEHSAR** a pour objectif de développer un outil de veille et d'anticipation du niveau de la sécheresse des sols argileux en France par la mesure in situ combinée aux algorithmes de l'intelligence artificielle pour une meilleure prise de décision et des applications comme l'humidification automatique et connectée du procédé MACH

Eléments clés

- Coût total : **2 651 874,00€**
- Aide PIA demandée : **1 971 316,00€**
- Durée : **60 mois (5 ans)**
- Début de projet T0 : **juillet 2024**
- Localisation projet : multisites (France métropolitaine)

Partenaires et financement France 2030

	Total général	Montant d'aide totale
Cerema	1 691 619,00€	1 433 936,00€
brgm	960 255,00€	537 380,00€

5. New approaches and innovative RGA projects for the adaptation

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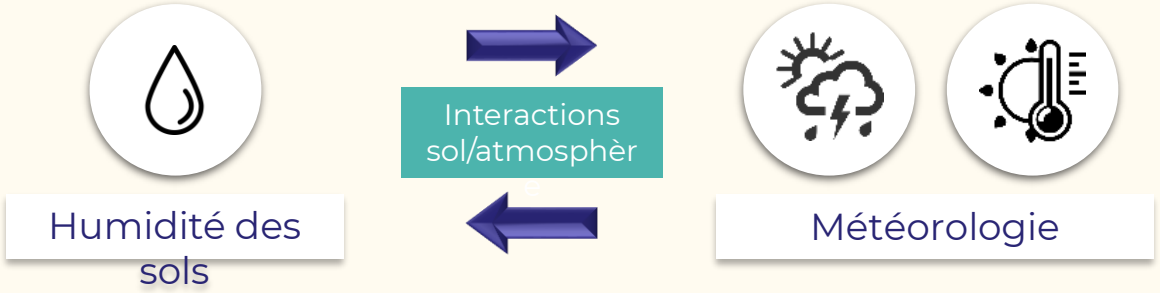
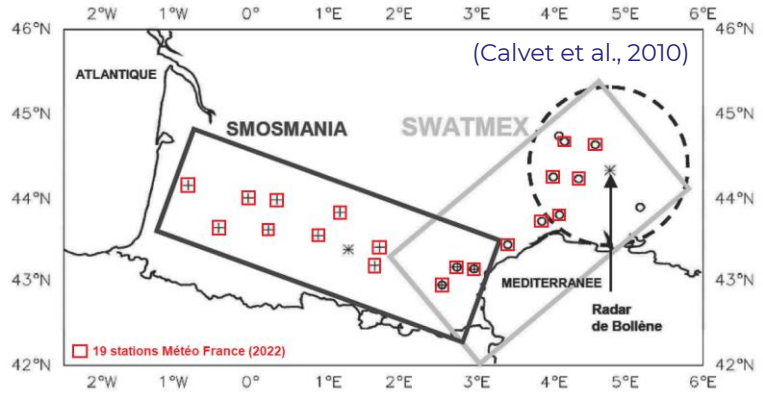
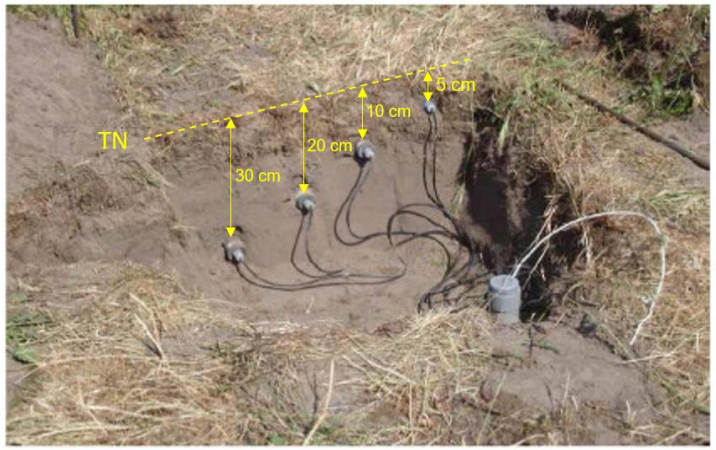
- **Étendre la mesure in situ** de l'évolution de l'humidité des sols argileux dans le contexte du changement climatique
- **SEHSAR → Coupler** données du sol et données météorologiques pour mieux adapter le bâti et prévenir la sécheresse des sols



- Météo France : mieux documenter l'indice d'humidité des sols utilisé comme critère pour la reconnaissance Cat-Nat
- Agriculteurs : mieux anticiper et gérer les besoins en eau des sols
- Services de secours : mieux anticiper les incendies

Etat actuel de la mesure de l'humidité des sols en





Sondes ThetaProbe ML3/ML2X après installation dans l'une des stations SMOSMANIA à 4 profondeurs (5, 10, 20 et 30 cm)

(CNRM-GAME, 2007)

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Thank you for your attention