XIIIth Workshop of developers and users of the soil-plant model STICS

The STICS model: Organization and progress

13-16 november 2023, Bordeaux

Presented by the Stics team coordination cell
Realised with the involvement of the Stics Project Team

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https://www6.paca.inrae.fr/stics_eng/

Outline

The STICS scientific community and its activities

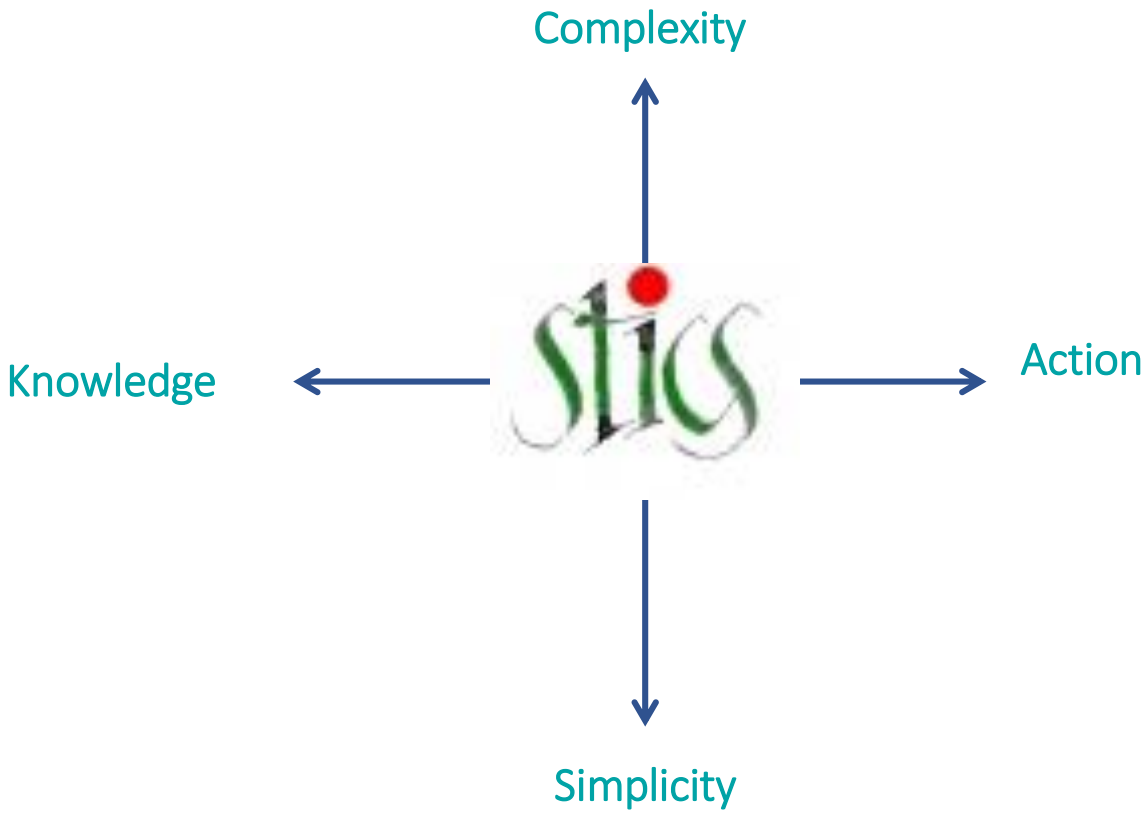
Highlights 2020-2023

Perspectives

The STICS scientific community and its activities

Objectives

Process based model of crops at field level,
balanced in terms of complexity level,
appropriate for both scientific research on agro-ecosystems
and for agro-ecological engineering



STICS objectives

- A tool box: Integrate the newest knowledge on atmosphere / plant / soil processes (e.g. P cycle, C & N reserves pools in perennials)
- A tool: Research at field level = mass and energy flux between atmosphere, plants and soil (e.g. benchmarking of cropping systems in terms of N flux in environment, impacts of climate change on yields and resources use)
- A tool piece: Contribute to operational tools for applied usage, at field or larger scales (e.g. regional production index, Biosphere models, automation, serious games...)

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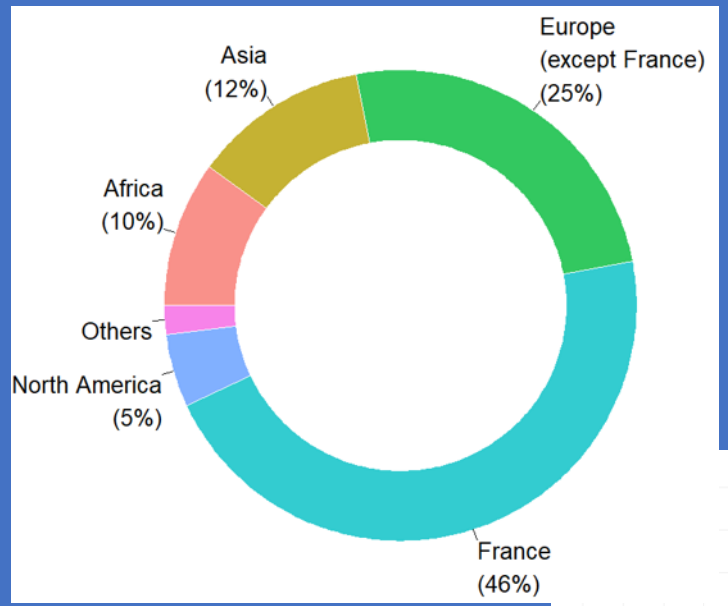
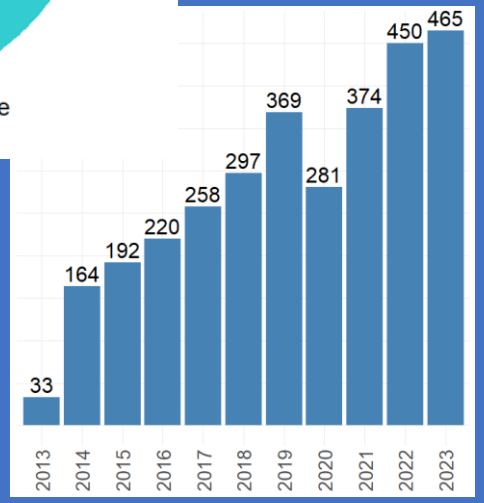
> STICS users network and project team

Users network





3103 new accounts since 2012

STICS Project team

26 members

https://www6.paca.inrae.fr/stics_eng/

STICS users network and project team

EPS (Stics Project Team): 26 researchers / engineers

- standard version: evolution, performances, diffusion, training
- development of research versions
- development of tools for the model
- coordination of the users network

GUS (Stics Users Group): network of STICS users

- scientific works performed with the model
- participation to the evolution of the model

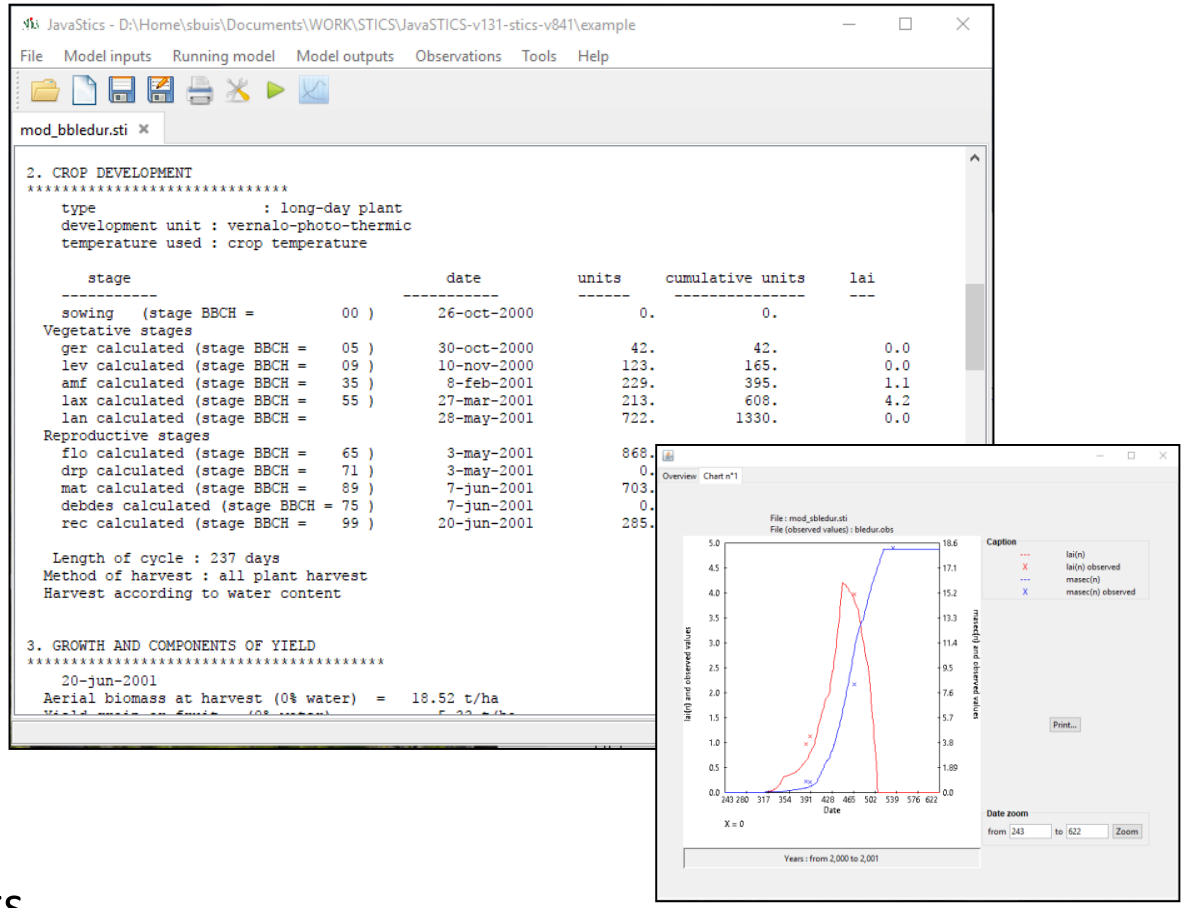
> Tools and software

STICS Crop model

- ~120 000 Fortran code lines
- One exe for all crops
- Linux/Mac/Windows compatible
- Exe and source code distribution
- Free Software Licence (CECILL-C)

JavaStics GUI

- Managing model inputs
- Running simulations (single / multiple, independent / linked, monocultures or intercropping)
- Parameters optimisation
- Graphical representation of simulated outputs



> Tools and software

SticsRpacks: scripting tools and coupling with mathematical methods

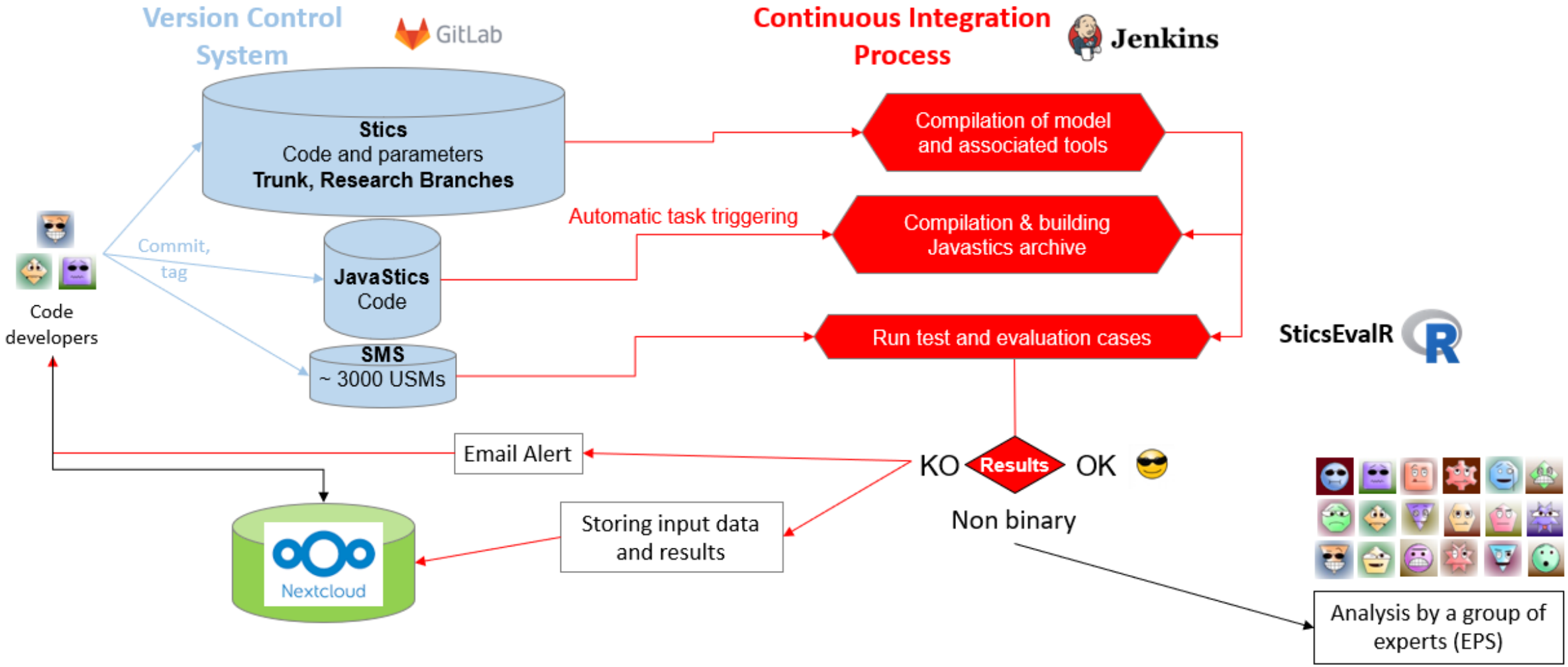
- packages collection, **open source** https://github.com/SticsRPacks

- **SticsOnR** and **SticsRFiles :** packages for managing STICS from
  - Finding names and setting parameters and variables
  - Handling input and output files
  - Running simulations (parallel, forcing parameters, etc.)

- **CroptimizR** and **CroPlotR : generic packages** for coupling crop models with mathematical methods :
  - Parameter estimation (Bayesian / frequentist, choice of criterion, consideration of constraints, AgMIP protocols, etc.)
  - Plots and statistical criteria

Used with various models: STICS, ApsimX, SiriusQuality, DSSAT + AgMIP calibration protocol
(Hermes, Daisy, Monica, PG ..., see Wallach et al. 2023)

Test and evaluation: automatic system



Test and evaluation: evaluation reports

Evaluation reports distributed for grass, maize, winter wheat, miscanthus, bare soil

Stics Performance Evaluation Report : Wheat

Authors: N. Beaudoin, F. Ferchaud, L. Strullu, B. Dumont, G. Jégo, E. Justes, D. Ripoche, S. Buis

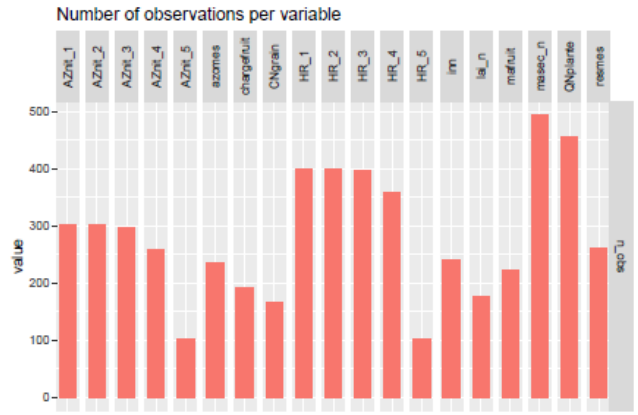
STICS version: V10.0.0

IdeSTICS version: r1956

Number of USMs: 222

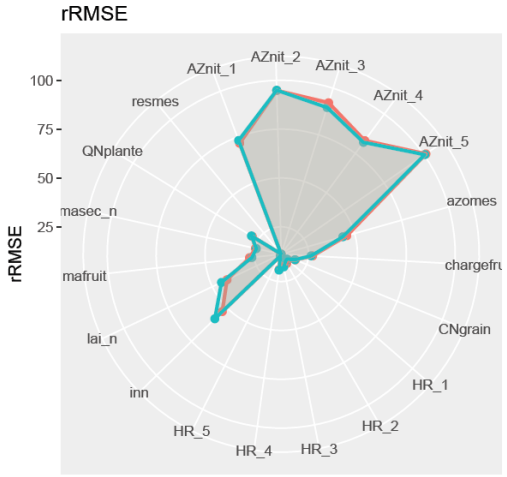
Number of cultivars: 9

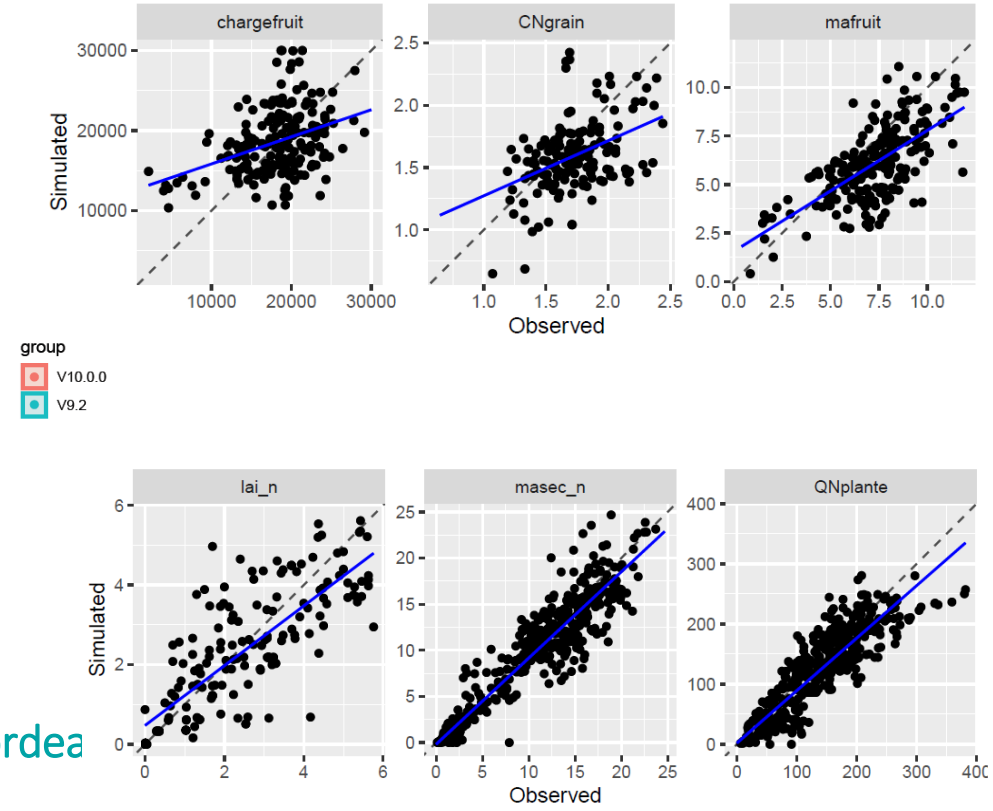
Cultivars names: Arminda, Talent, Thesee, Soissons, Promentin, Sideral, Thésarmin, Thétalent, Shango



The evaluation dataset includes 222 USMs not used for model calibration, 9 cultivars and a large number of observations (>90) for all evaluated variables.

- Description of the evaluation dataset
- Evolution of performances wrt former Stics versions
- Global and specific analysis of performances





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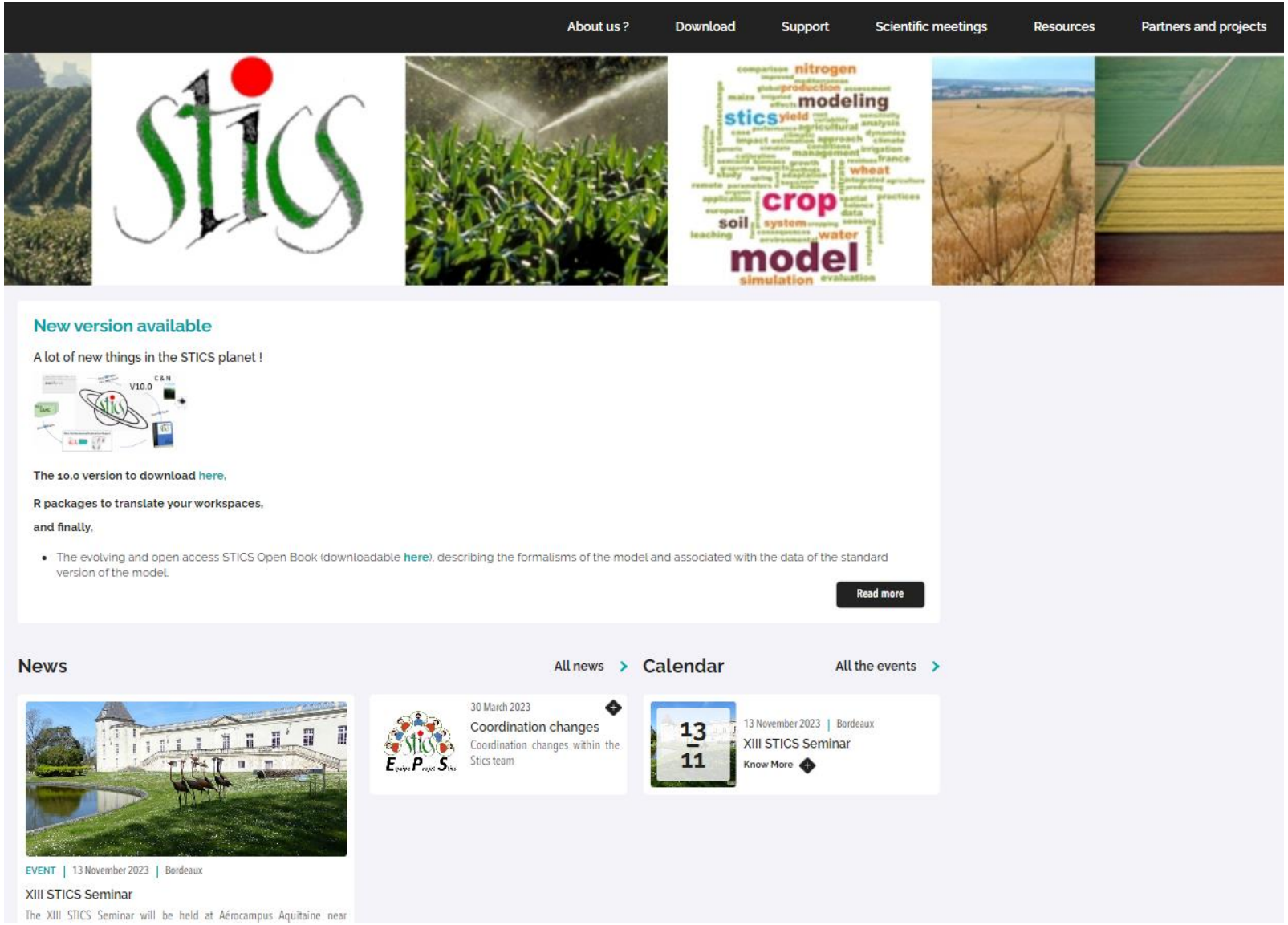
> Links between user network and project team

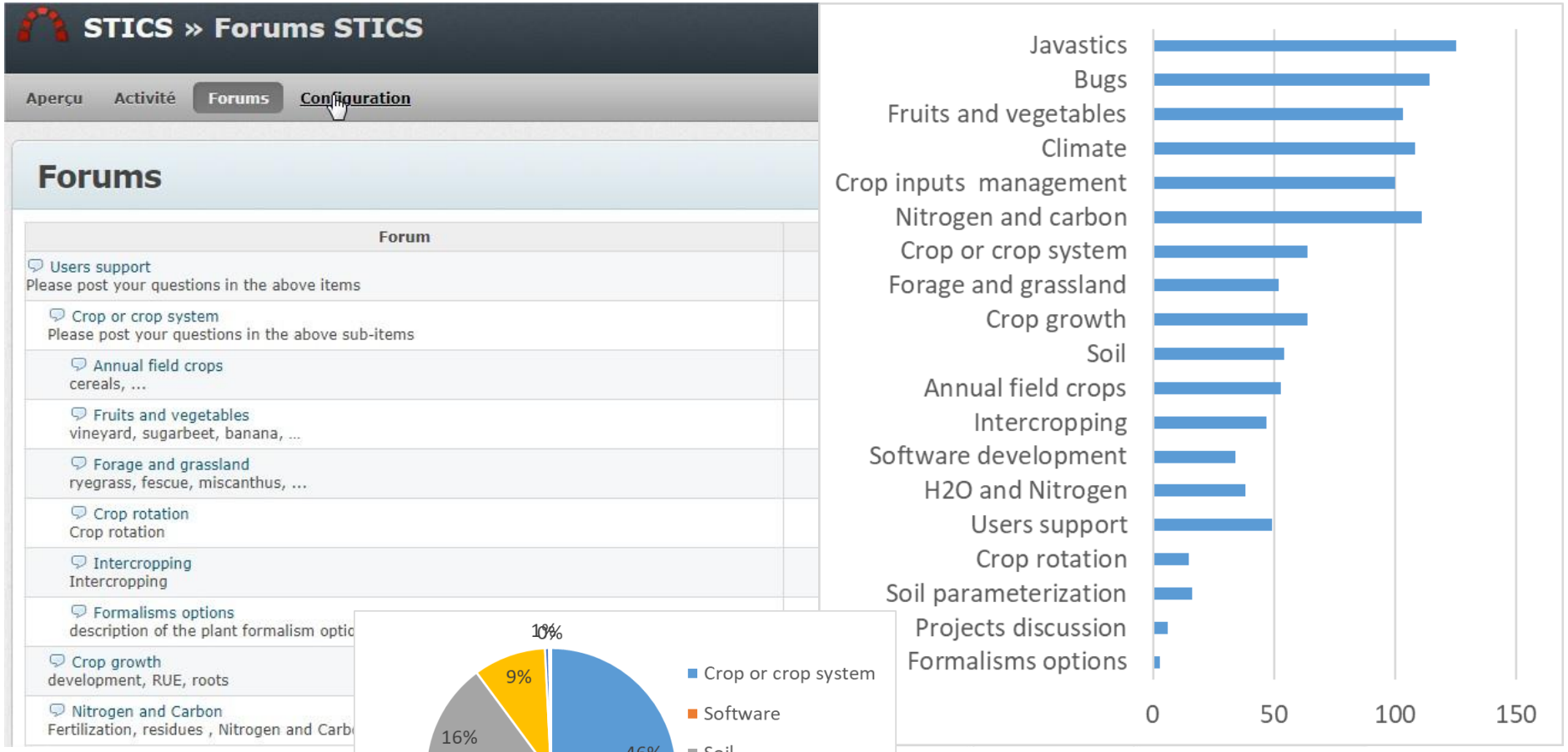
- ❑ **Communication: website, forum, email list**
- ❑ **Training courses**
- ❑ **Contribution to STICS development**
- ❑ **STICS seminars**

> The STICS website

https://eng-stics.paca.hub.inrae.fr/



> The STICS forum



# of questions per theme

Contribution to STICS development

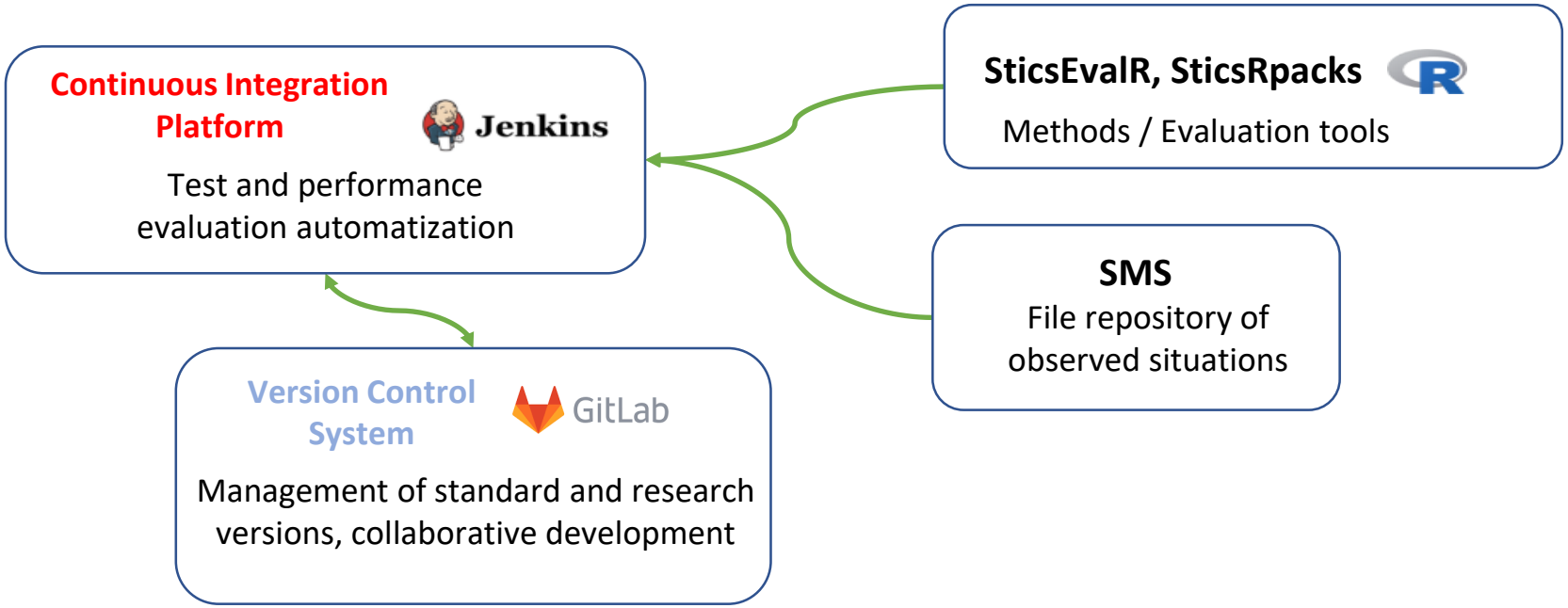
Open to user experts

⇒ Improvement / implementation of formalisms, (re)Parameterization of crops / cultivars, ...

⇒ Research branches opened on demand

⇒ Access to the team development environment (versioning system, automatic tests, data base, …)

⇒ Protocols for integration of the proposed modifications in the standard version



> The STICS workshop

Every two years

2003 Arles, 2005 Carry le Rouet, 2007 Reims, 2010 Sorèze, 2012 Sainte Montaine, 2015 Rennes, 2017 La Rochelle, 2020 Montpellier (ICROPM 2020), 2023 Bordeaux

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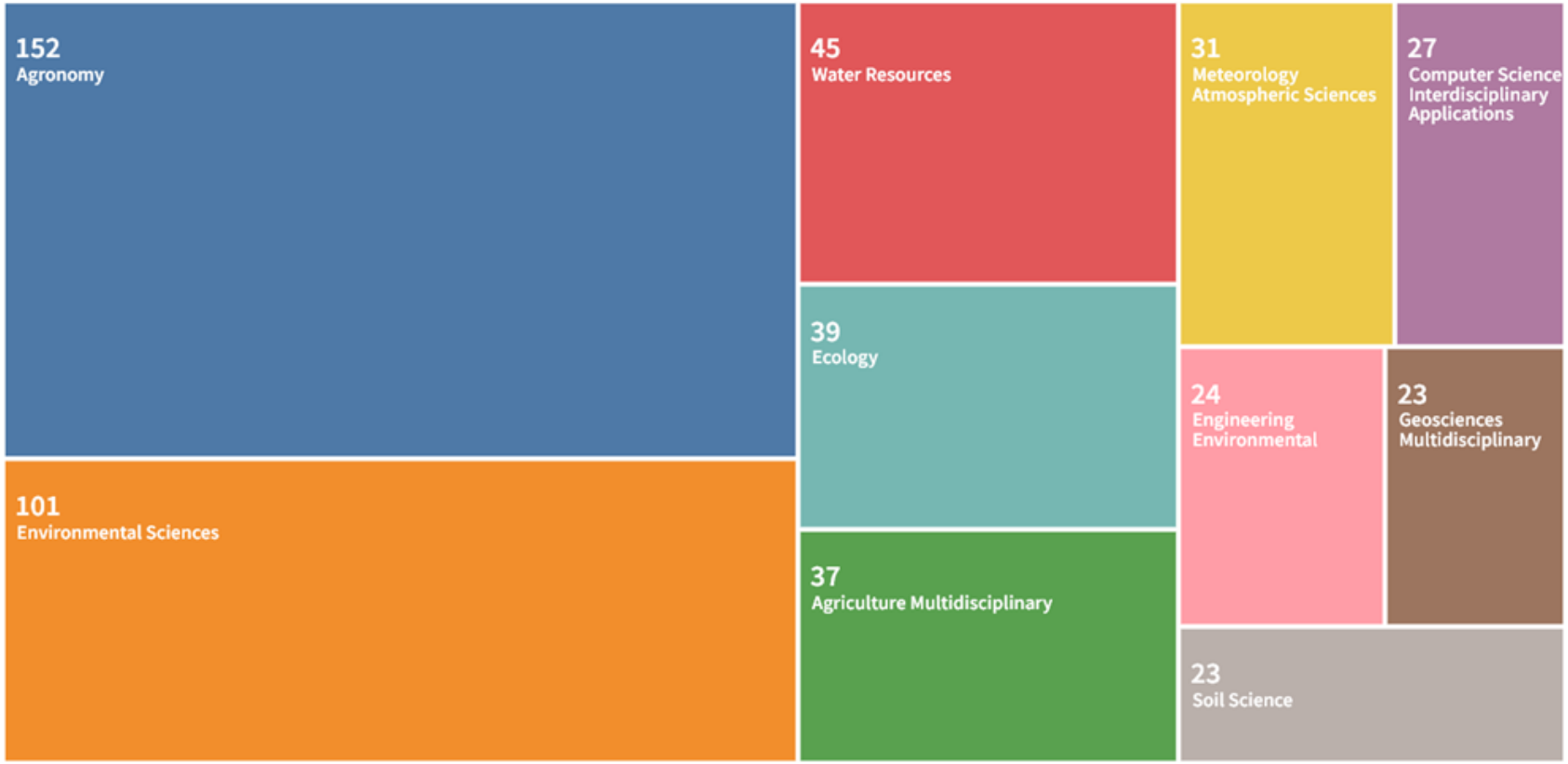
The scientific community: Publications and citations

352 articles retrieved from the WOS for a total of 392 articles -> cited by 10159 articles (fev. 2023)



Agronomy and environment : 50%
Water resources and ecology : 17 %

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https://www6.paca.inrae.fr/stics_eng/

The scientific community: Publications and citations

In February 2023 : **352 publications WOS** cited in more than 10 000 articles (**/ Feb 2020**)

Citing Articles

10,159 / 4 879
Total

9,812 Analyze
Without self-citations

Times Cited

16,401 / 7 784
Total

46.59 / 28.94
Average per item

14,397
Without self-citations

61 / 43
H-Index

Highlights 2020-2023

Evolution of the STICS Team: the team in 2023

Ecophysiology, cropping systems & climate/microclimate

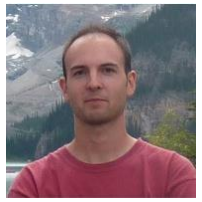

Eric Justes
Intercropping Systems


Marie Launay
Agrophysiology & fungal diseases


Julie Constantin
Long-term simulations, Cover crops


Marie-Odile Bancal
Ecophysiology Plant health


Benjamin Dumont
Wheat & decision tools


Guillaume Jégo
Energy balance and continental conditions


Inaki Garcia de Cortazar
Vineyards and perenial crops


Jean-Louis Durand
Grassland and Maize


Gaetan Louarn
Ecophysiology & coupling with FSPM


Didier Combes
Bioclimatology


Gatien Falconnier
cropping systems & participatory approaches.


Rémi Vezy
Perennial tropical crops


Anne Isabelle Graux
Grassland


Loïc Strullu
Energy and perennial crops

Soil, nutriments, C, N, H_2O transfers and evolution


Christine Le Bas
Soil properties


Hugues Clivot
Soil micro-organisms

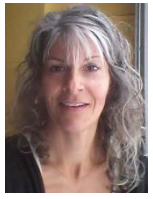

Alain Mollier
Phosphorus


Florent Levavasseur
Organic waste products


Joël Léonard
N_2O emissions


Fabien Ferchaud
Soil N transfers and C storage

Administration


Isabelle Le Mouëllic

IT and scientific computing


Patrice Lecharpentier
Development


Samuel Buis
Mathematical Methods


Eric Casellas
Modularization


Hélène Raynal
Multisimulations


Cyril Gandon
Development

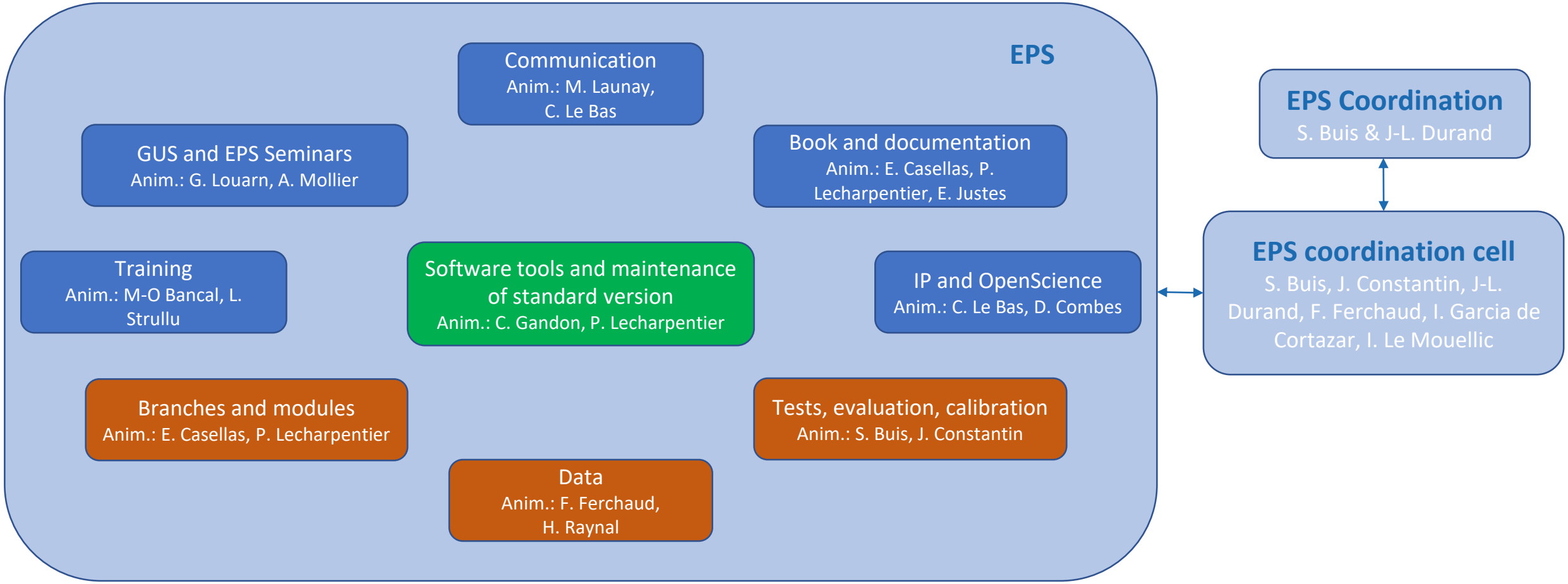
Retirements: Bruno, Domi, Françoise, Nicolas, Patrick

Departure: François

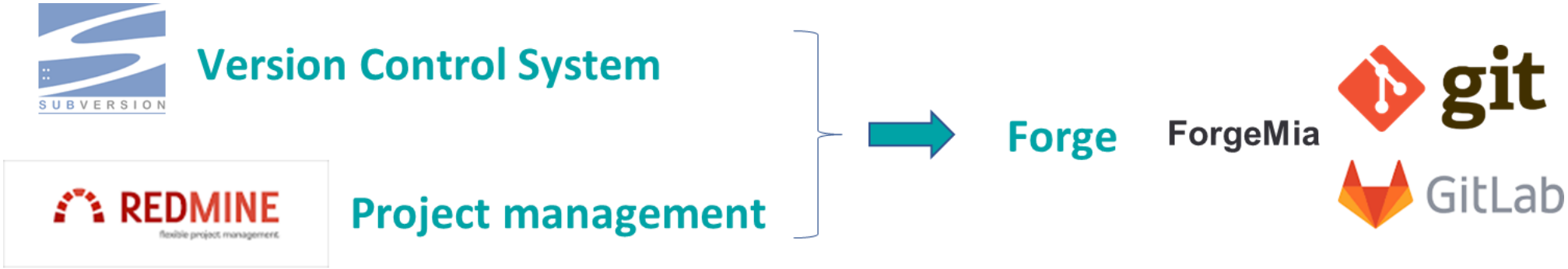
Newcomers: Cyril, Didier, Isabelle, Hélène, Hugues, Marie-Odile

Change of the animation cell

Evolution of the STICS Team: working groups



Evolution of code management



- Global **Code reviewing** => cleaning, improvement of robustness, increasing strictness of the compiler...

- Moving towards **Modern Fortran (2018)**: modules everywhere, dynamic memory allocation, use Fortran Package Manager (fpm) and Fortran Standard Library (stdlib)

- **Continuous Integration** in GitLab forge: compilation, unit tests and End 2 End tests

fpm

Evolution of code availability

STICS is open source since beginning 2021 (V9.2 and following)

- Distributed under CeCILL-C license
  - Free Software license
    => use of STICS code is free for any purpose
  - Weak copyleft license
    => if you modify the STICS code **AND** diffuse it, it must be under CeCILL-C license
- Source code available on Redmine

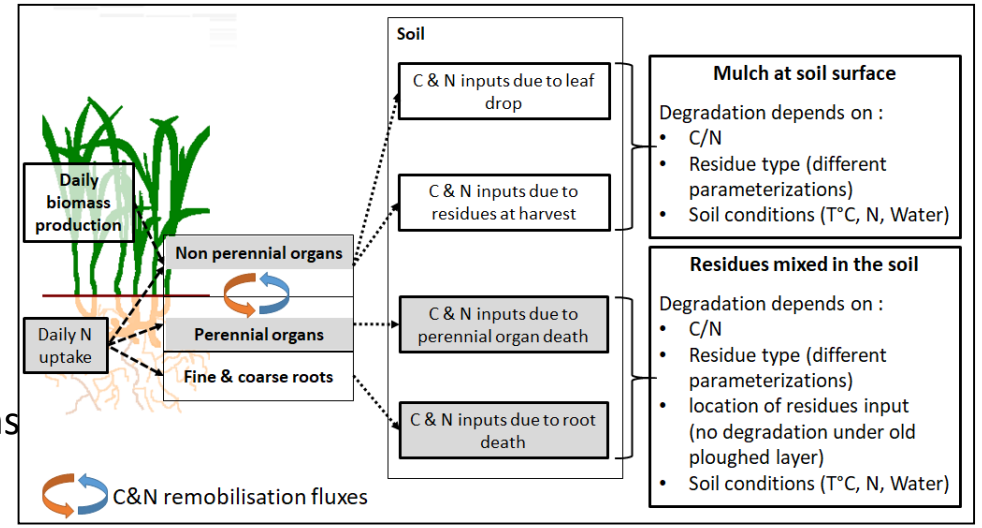
STICS V10.0 and JavaSTICS 1.5.1

⇒ **Available since 27/10/2022**

⇒ **>1200 downloads**

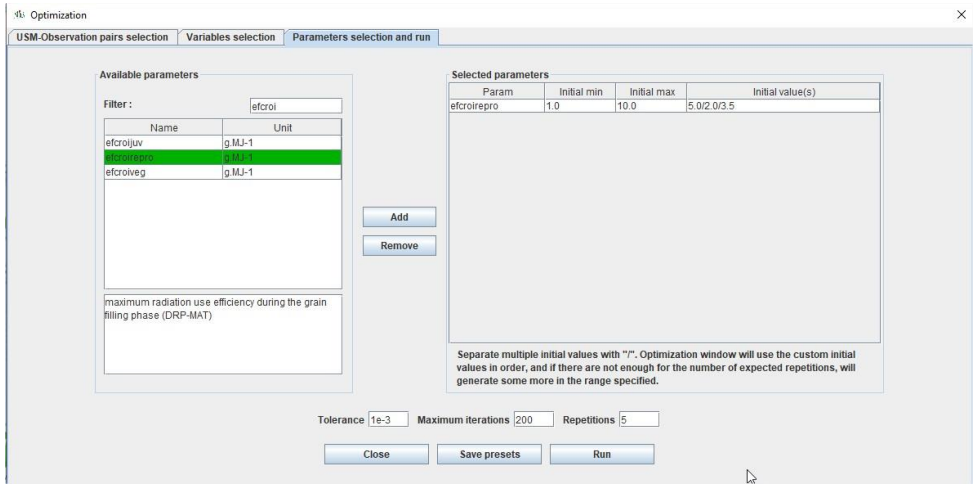
STICS model

- New Formalisms
  - Better consideration of reserves (C&N) for perennial crops
  - Dynamic description of N demand and root death
  - Introduction of effect of photoperiod on biomass and N allocation
  - Improvement of effect of mowing dynamic on biomass production
  - Possibility of destruction of perenial crops and effects on successions
- New crops
  - Miscanthus
  - New parameterization for wheat



Javastics

- Features:
  - Improvement of parameter optimization procedure
  - Improvement of dynamic graphs management
  - Improvement of ergonomy and responsiveness
  - Use of java 11
  - Improvement of simulation speed
- Some bugs fixed

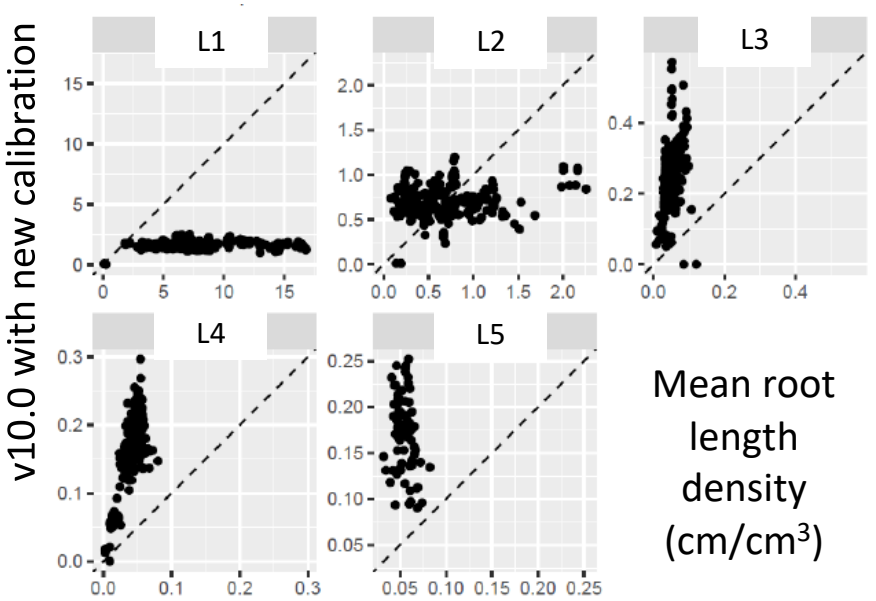


Improvement of root parameterization

- STICS v10.0 includes **new formalisms** to simulate the daily allocation on N to root growth, the root turnover during crop growth and to improve the vertical distribution of roots in the soil profile
- Using these new options requires to **revise root calibration** in order to simulate correctly not only the crop water and N uptake but also the C and N fluxes in the soil linked to root dynamics

- **Definition of a methodology** to calibrate root parameters, based on:
  - ✓ sequential activation of new options and calibration of the corresponding parameters using literature data and/or other models (ArchiSimple)
  - ✓ comparison between simulated root variables and literature data (shoot:root, N in roots, etc.)
  - ✓ global evaluation using the STICS evaluation database
- **Application** to alfalfa, maize, pea, rapeseed, winter barley and winter wheat

Ex.: simulated root length density of winter wheat for different soil layers



SticsRPacks: new versions

=> See presentation Buis & Lecharpentier at 14:00

Research branches

Perennial crops

- Integrated into STICS v10.0.0 (oct. 2022)

Intercrops

- Improved formalisms to simulate cereal-legume mixtures *=> Juste et al. (Thursday at 08:45)*

Viticycle

- Improved formalisms to simulate grapevine yield *=> Strullu et al. (Tuesday 16:30)*

Phosphorus

- Integration of the P cycle in STICS *=> Seghouani et al. (Wednesday 10:30)*

Grassland

- Corrections for grassland (senescence of the residual biomass after cutting, C and N inputs to soil with grazing) *=> Graux et al. (Tuesday 14:40 and Wednesday 14:40)*

Pathogen (crop foliage diseases)

- Recoding in modular format and new formalisms *=> Vidal et al. (Wednesday 14:00)*

IDE-STICS

Why?

- Gather experimental data useful to test STICS, with a large range of soil, climate, managements and output variables
- Include model inputs, observed data and metadata

How?

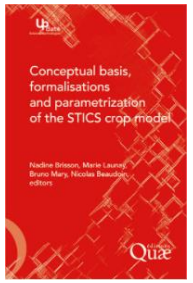
- An SQL database and a web interface
- Main functions:
  - Input of STICS files (workspace) and an Excel metadata file
  - Visualize available data
  - Search and data export (formatted for STICS)

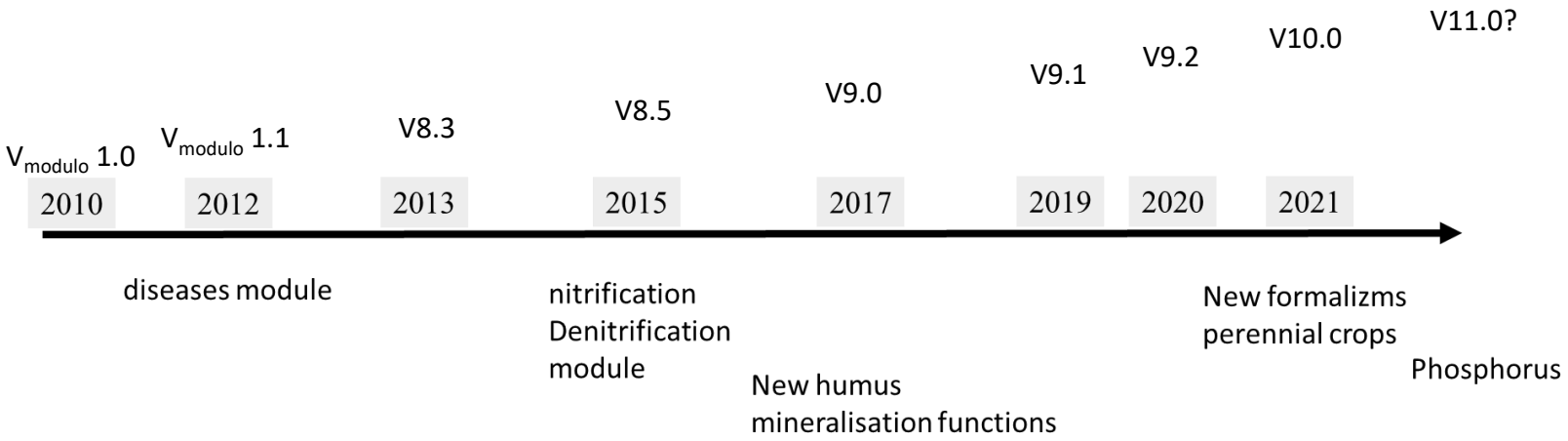
Where are we?

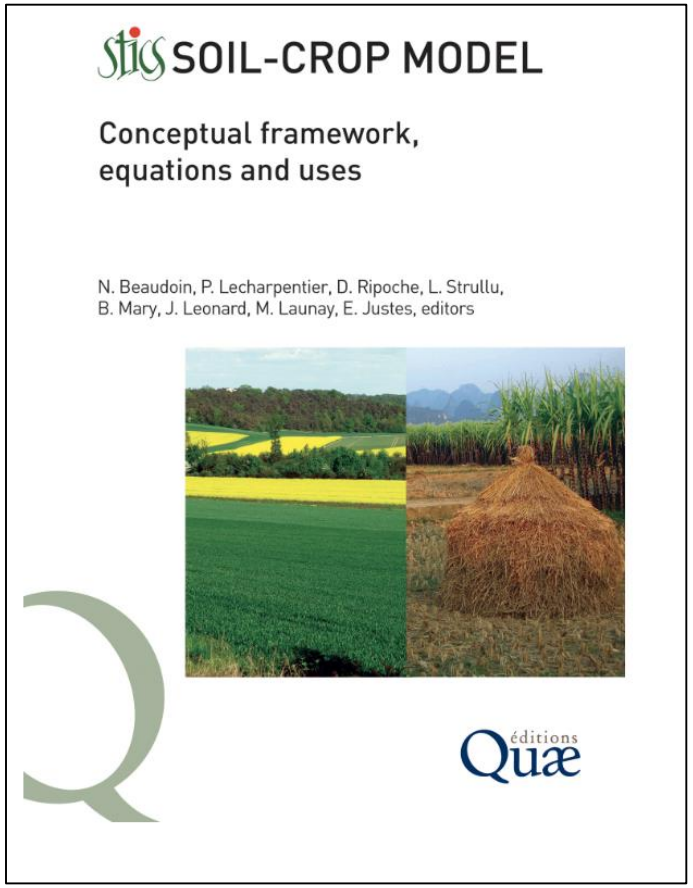
- Under development and test, first version soon available

> Documentation: the STICS book, new edition

- 29 authors, ~300 pages
- **Electronic version available for free** (CC BY-NC-ND license): html, epub, pdf
- Paper edition on order
- Objective: **continuous evolution** according to the versions of the model (RMD format under version management system)







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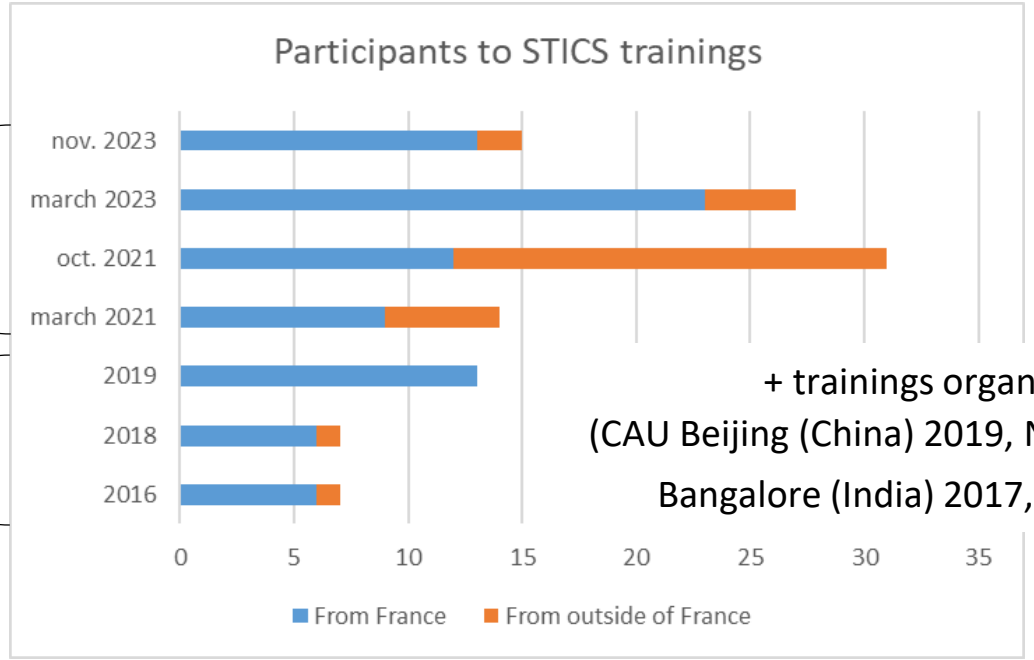
A new design for STICS Trainings

- Update of course materials for STICS V10
- Training session divided in modules
- Practical use of STICS from JavaSTICS and R packages
- Webinar instead of classroom-based courses

Module 1	Module 2	Module 3 (option)	Module 4	Module 5
• Stics overview • Soil processes formalims	• Crop growth and development	• R packages for STICS	• Specificities of perennial crops and crop rotations	• Model evaluation and calibration: principles and existing tools
PW 1: JavaSTICS interface Creation of a USM	PW 2: Effect of cultural practices, soil and climate on model outputs (plant and environment) + Homework presentation	• Inter-cropping	PW 3: Simulation of crop rotations including a perennial crop	PW 4: Integration of observed data and example of parameter calibration Presentation of homework results



Webinars

Classroom-based courses

=> more frequent trainings, with more participants and more foreigners

+ trainings organized out of France
(CAU Beijing (China) 2019, NWAFU Yangling (China) 2017, Bangalore (India) 2017, Edimburgh (UK) 2016, …)

Some projects

REDELAC project - studies the impact of climate change on dairy farms (P. Chabrier, AI Graux)

CarSolEI project - carbon storage (AI. Graux)

Agriphotovoltaic (J. Vernier)

Viticycle project - Grapevine yield simulation in Champagne (L. Strullu)

ISOP V10 - Update of ISOP system with the new STICS version (JL. Durand)

AgMIP calibration project - last results using the STICS (S. Buis)

Soybean ERANET and ANR project - European production (J. Constantin)

Intercropping projects (InterCropValues) - formalisms evaluation (Vezy, de Freitas, Kherif)

and many others about different topics, focus on different objectives, and funded by different institutions

Perspectives

Software

Integrate research branches in standard version

- Intercrop
- Vineyard
- Grassland
- ...

Provide new parameterizations

- alfalfa, maize, pea, rapeseed, winter barley, ...

Facilitate contributions

- adapt contribution rules and tools to new version control and evaluation systems
- make contribution rules more visible and friendly
- provide more documentation for developers

Change license of JavaSTICS and STICS executable (=> CeCILL-* license)

Documentation, data and evaluation

Deliver first version of IDE-STICS and integrate new datasets

Improve automatic test and evaluation system

- add new type of automatic evaluation (long term, intercrops, ...)
- generate and distribute evaluation reports for more crops
- integrate IDE-STICS

Make the STICS book evolve with new model versions

Communication and training

Revise website content

Build a new advanced training module on how to adapt STICS to new crops / cultivars

Transfer

As a tool for action, STICS is requested by various agencies, territories ,

—> impact of land management on water quality

—> impact on C sequestration

—> optimization of solar panels operations over crops

—> evaluate the crop losses for farmers subsides

etc....

The STICS team EPS always engaged in many of such tasks.

However, the STICS team cannot satisfy the full fast **growing** demand.

Still, within the framework of institutional goals, INRAE, CIRAD ... the STICS team needs to answer.

—> Need for organizing three ways currently explored by the STICS team:

- **Capacity building**. The formation STICS, two sessions per year, aprox 20 students per session in France and abroad
- **Supervision of PhD** with partners (CIFRE...) and promote the employment of PhD with modeling skills
- **METYS** business unit of the INRAE subsidiary **INRAE Transfert** include STICS modelers (under evaluation)

And now …

- Thanks to be there
- Have a good workshop

- Idea box available !