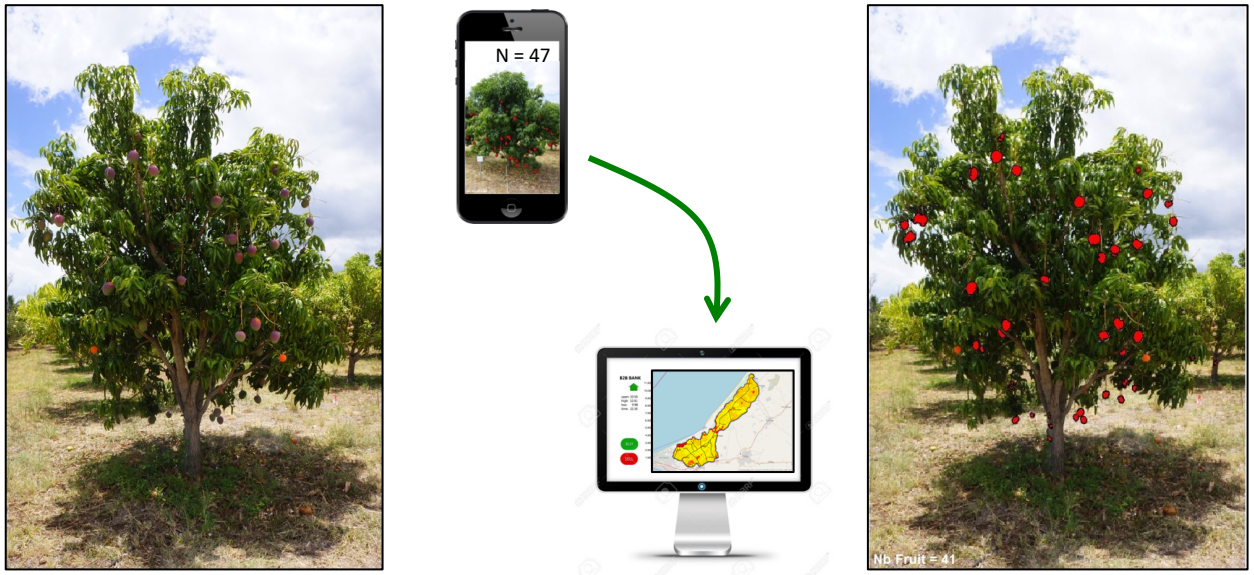
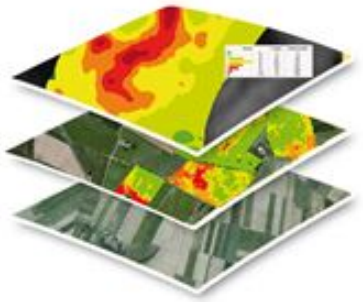
PixFruit: a digital platform to inform the agricultural sector on fruit tree yields in the tropics



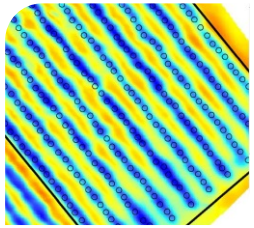
E. Faye, UPR HortSys, CIRAD | 4 Dec. 2019 | Saclay, France
emile.faye@cirad.fr

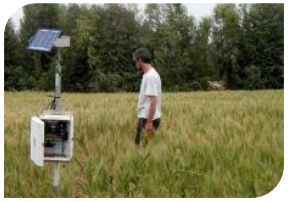
#DigitAg



The Digital Agriculture Convergence Laboratory,

Montpellier, France





#DigitAg's objective is to promote the **development of digital tools in agriculture** (from data acquisition to data processing and uses) by putting together **research and higher education ressources** in France, Europe, and Southern countries.

What is #DigitAg ?

400 staff members with **interdisciplinarity crossings** between agronomy, engineering sciences (computer sciences, maths, electronics, physics …), economic, law, and social sciences..

7 years from 2017
9,9 M€ public support
=> World reference in Digital Agriculture

Public

INRA SCIENCE & IMPACT
cirad
Inria INVENTEURS DU MONDE NUMÉRIQUE
irstea
Université Montpellier
SupAgro Montpellier
AgroParisTech

17 partners

Private

acta LES INSTITUTS TECHNIQUES AGRICOLES#
IDATE DIGIWORLD
smaG Smart Agriculture
itk
vivelys TASTE THE INNOVATION
Pera GROUPE PELLENC
axLR SATT
AGRISCOPE À L'ÉCOUTE DU VÉGÉTAL
terraNIS New Information Services

Digital Technos & agroecology, crop and animal production, genotyping, crop protection, farm advisory services, agri. territorial manag., crop value chains, dev. agricultural sector in the developing countries.

Let’s be connected!

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http://www.scoop.it/t/digital-agriculture

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https://www.youtube.com/channel/UC-wt1R8NXmULYHBbUeA8GqA

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www.hdigitag.fr

CHAIRE AgroTIC

Le MAS numérique

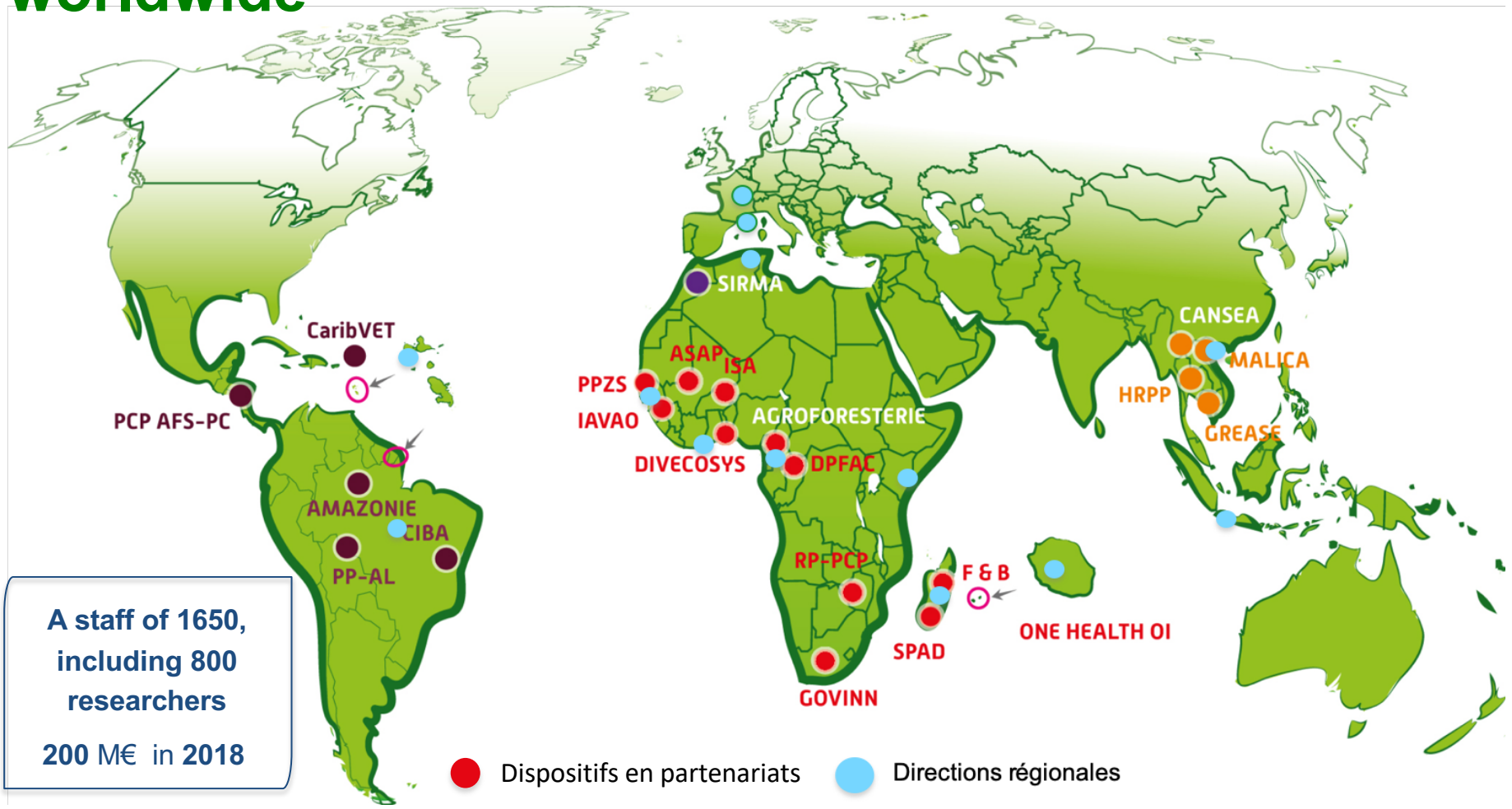
cirad

AGRICULTURAL RESEARCH
FOR DEVELOPMENT

Working together for tomorrow's agriculture

- National public institution status, but a global mission
- Targeted research for development
- Based on 50 years' experience in the field, and an original approach

Research and training platforms in partnership worldwide



A staff of 1650, including 800 researchers

200 M€ in **2018**

CIRAD generates knowledge and helps build capacity, in support of agricultural and rural development with specific experience of the tropical commodity chains

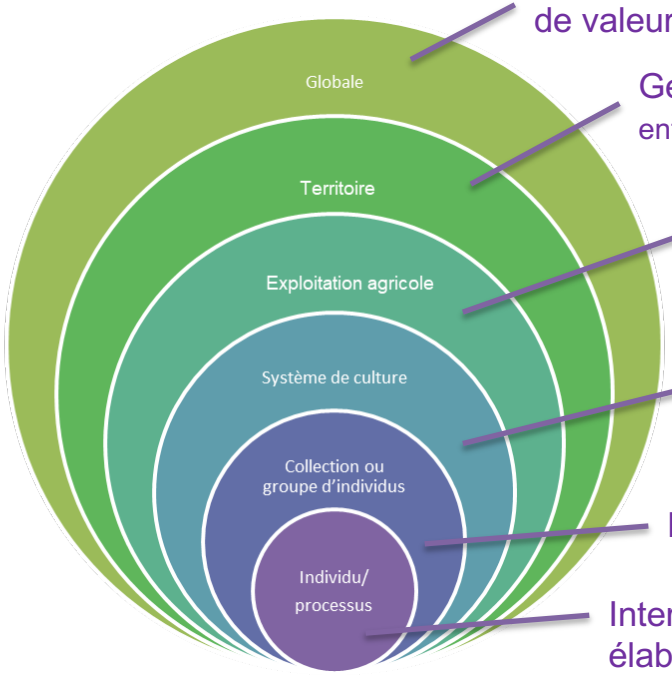
UPR Horticultural Systems – HortSys

Address the global and local challenges of tropical horticulture to fullfill the growing demand in healthy tropical fruits and vegetable.

- Developing innovations and designing with the actors sustainable horticultural systems ...

50 persons

Martinique
Guyane
Sénégal
Côte d'Ivoire
Montpellier
Tanzanie
Kenya
Madagascar
Mayotte
La Réunion



Evaluation environnementale et économique des chaines de valeur horticoles (ACV), agronomie globale

Gestions des bioagresseurs (mouches des fruits, entomovectoring), des pollutions (Chlordécone)…

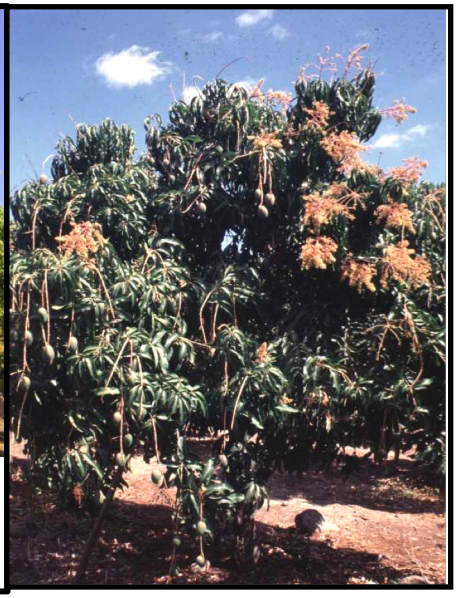
Evaluation économique des innovations, évaluation de la durabilité des exploitations…

Co-conception de systèmes innovants, maraichage sous filets, biocontrole, diversité fonctionnelle

Modélisation, prévision de récolte…

Interaction plante/insecte (écologie chimique) , élaboration du rendement (mangue)…

Mango is a complex tree!



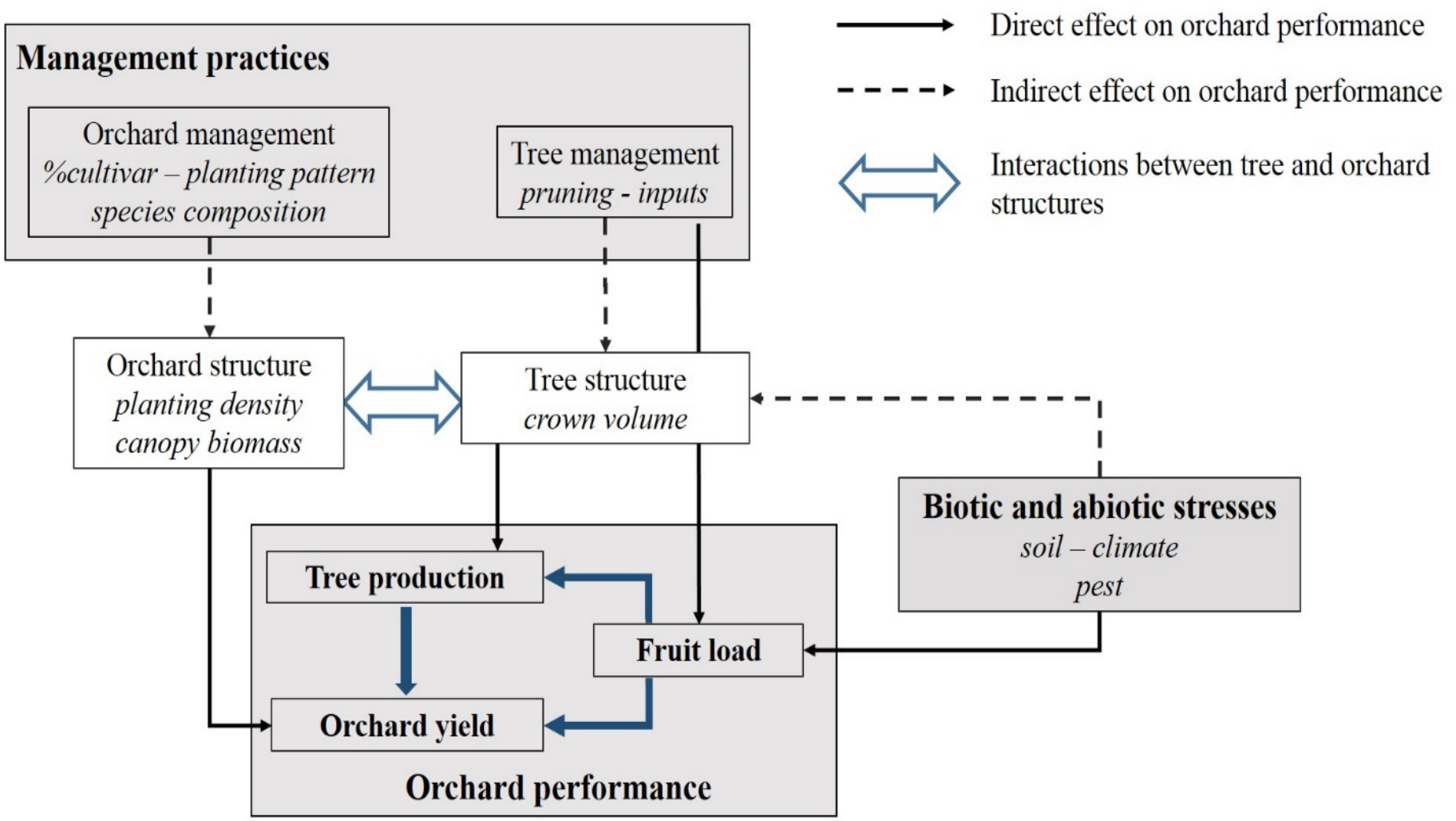
Physiology: alternance, asynchronism

Manual field count
tedious & imprecise

- No mechanistic modelling of yield elaboration
- No data on cultivated areas
- Spatiotemporal heterogeneity in production

Mango Production
Tree / Orchard / Basin
??

Drivers of mango yields



Sarron et al. In prep.

Mango in West Africa

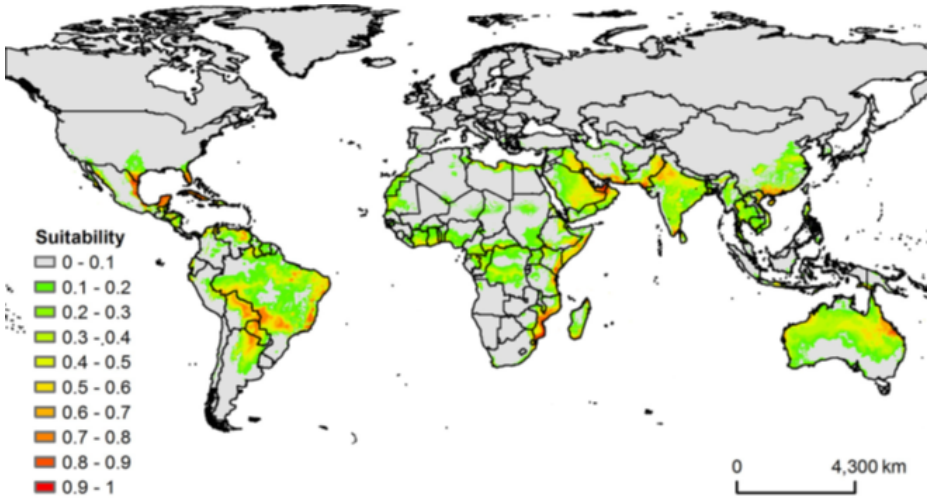
5th fruit production WW

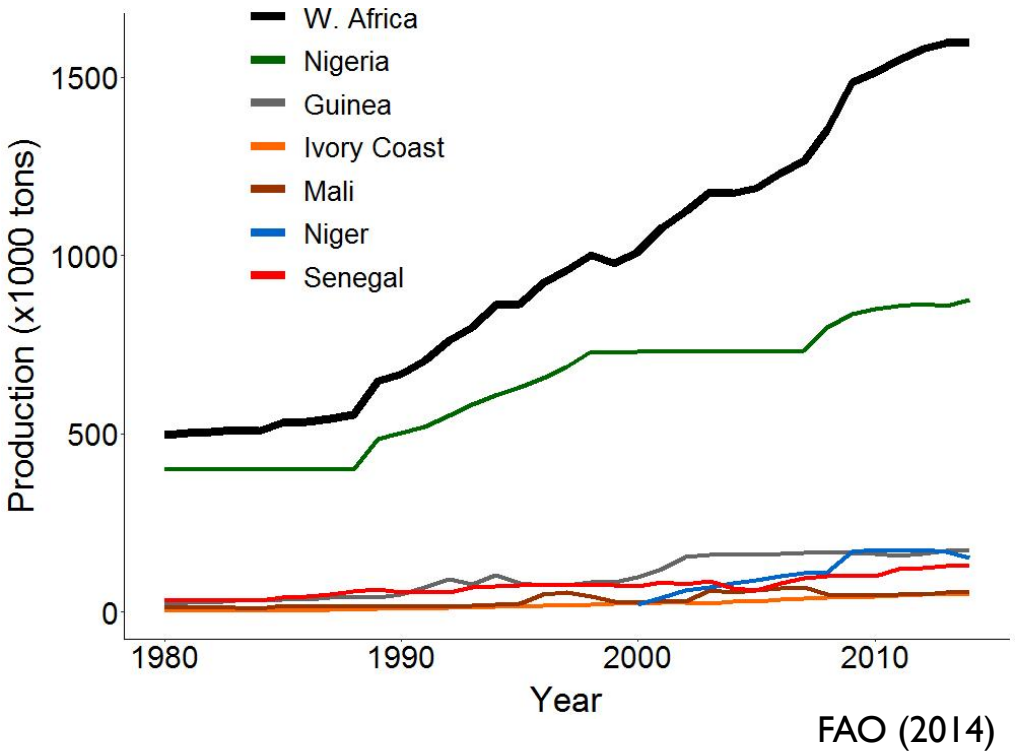
Market **2 Billions** US$

World = **50 Mt/y**

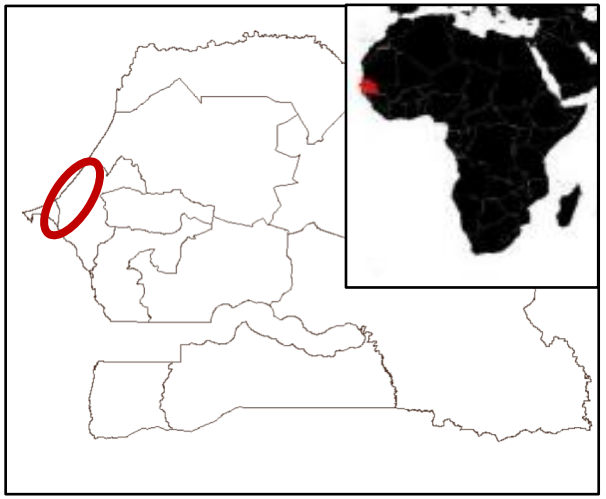
West Africa = **2 Mt/y**

Monfreda et al. 2010

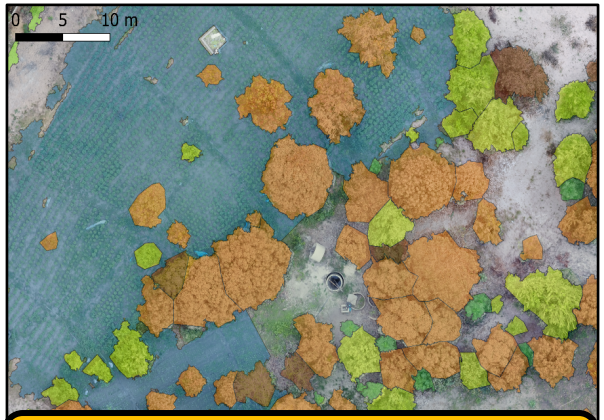




FAO (2014)

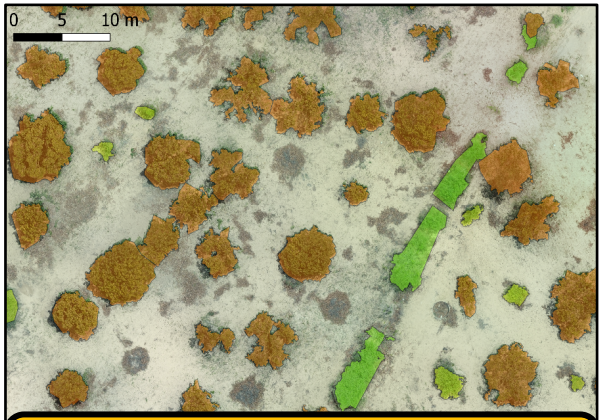


Mango cropping systems in West Africa



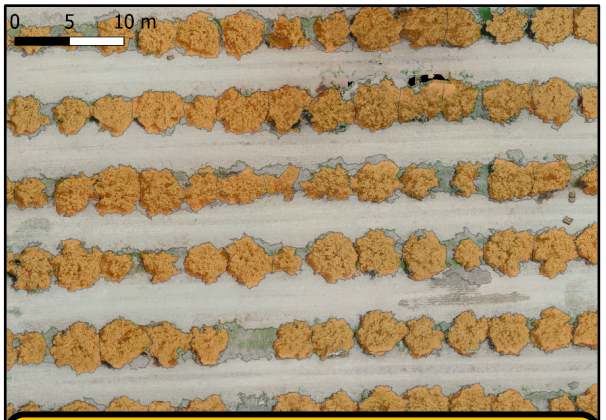
5 <Y <15 tns/Ha

Agroforestry
Intercropping



<5 tns/Ha

Extensive
Traditional



20 - 40 tns/Ha

Intensive – export
Monocultivar

Extensive – 80%MUS = < 5 tns/Ha picking

Diversified – XX MUS = 5 < Y < 15 tns/Ha

Mango, citrus, papaya, cashew, annual crops…

Intensive export - 5%MUS = 20 < Y < 40 tons/Ha

Fertigation, prunning, Pest & diseases…

The Niayes production area

1st horticultural basin

The needs of the stakeholders in the mango sector

- Yields are **strategic** and **key information** for both **growers** and **stakeholders** of the value chains involved in market supply and exports.

- In developing countries, information on yields is **barely available** nor existing, making it difficult to improve the efficiency of the production process.

- "***Nobody knows the present quantities of mango fruit produced***." not the growers, not the buyers, nor the national agricultural statistics organism.

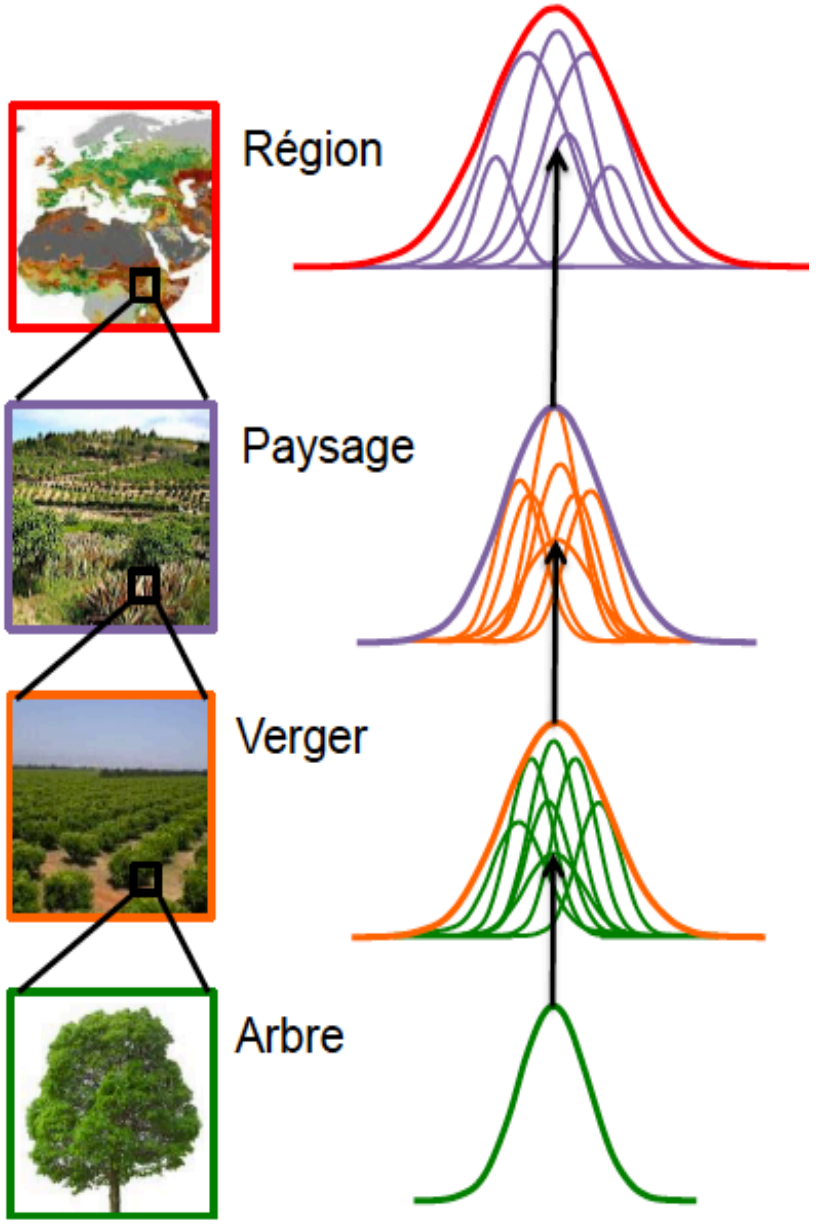
Actors	Needs
Growers	**Production - Relationship with buyers**
Buyers/exporters	**Supply**, harvest date, **Relationship with growers**
Local authorities	**Mean yields** in their districts
Gov. institutions	**Agricultural policies** (DAPSA agri. stats, ANCAR advices)
Intern. agencies	**Value chains**, development (FAO, AFD, USAID...)
Research org.	**Reliable Big Data,** drivers of production…

Questions

What is the land productivity of mango agriculture ?

How to estimate and/or forecast the production?

At which time and space scale ?

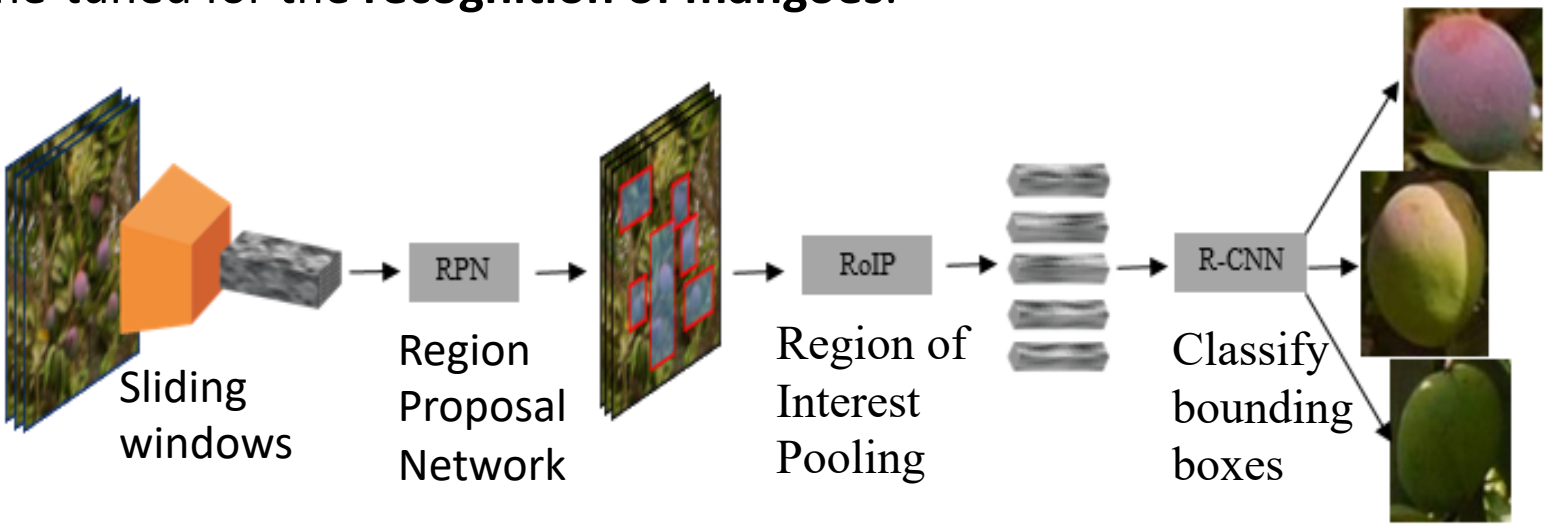


Estimating mango yields at the tree scale

Using a deep learning approach

Convolutional Neural Networks have proven in the last years to be very effective tools **for fruit counting** and **yield estimates** (Gongal et al. 2015 rev.).

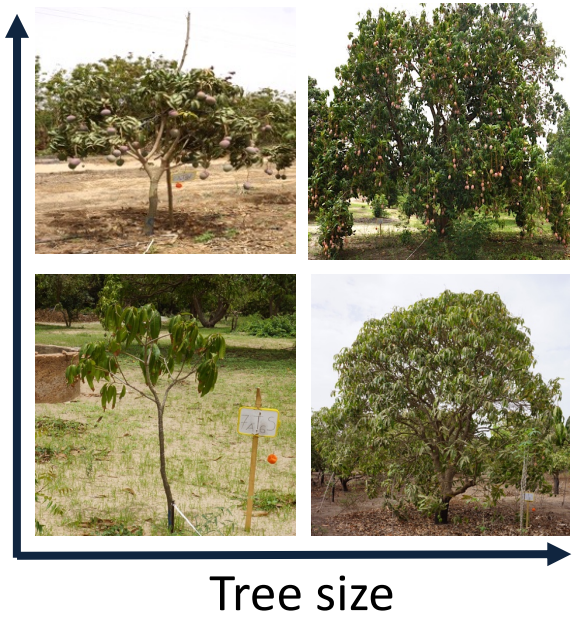
Basically, CNN pre-trained on **ImageNet** for the task of classification and then fine-tuned for the **recognition of mangoes**.



- Faster R-CNN, a specific network to quickly detect and classify objects in images. Has been fine-tuned for mango detection in RGB Images.

*Ren, S., He, K., Girshick, R., Sun, J.. (**2016**) Faster r-cnn: Towards real-time object detection with region proposal networks. In: Advances in neural information processing systems, 91–99*

Images acquisition



3 cultivars (Kent, Keitt, BDH)

300 trees X 2 sides

X 3 phenol. stages =

1800 images/year

Annotations
(10459 fruits)

Field counts
(14061 fruits 65 trees)

Deep Mango features

- Key points: training and validation
  - Training: **150 images** RGB (4000x6000 pixels) with **3 000 annotated fruits** (3 experts) selected to form a representative set in terms of shape, colour, sunlight conditions or occlusions. (15,000 iterations)
  - Validation: **450 images** , **7 000 annotated fruits**, tested with a confidence threshold of 0.7
  - **F-measure** and **Loss value** to assess the performances of the CNN.
  - **The non-maximum suppression** (NMS) pre-vents multiple detection of the same object (dixed at 0.25).

Deep Mangoes: from fruit detection to cultivar identification in color images of mango trees. 2019

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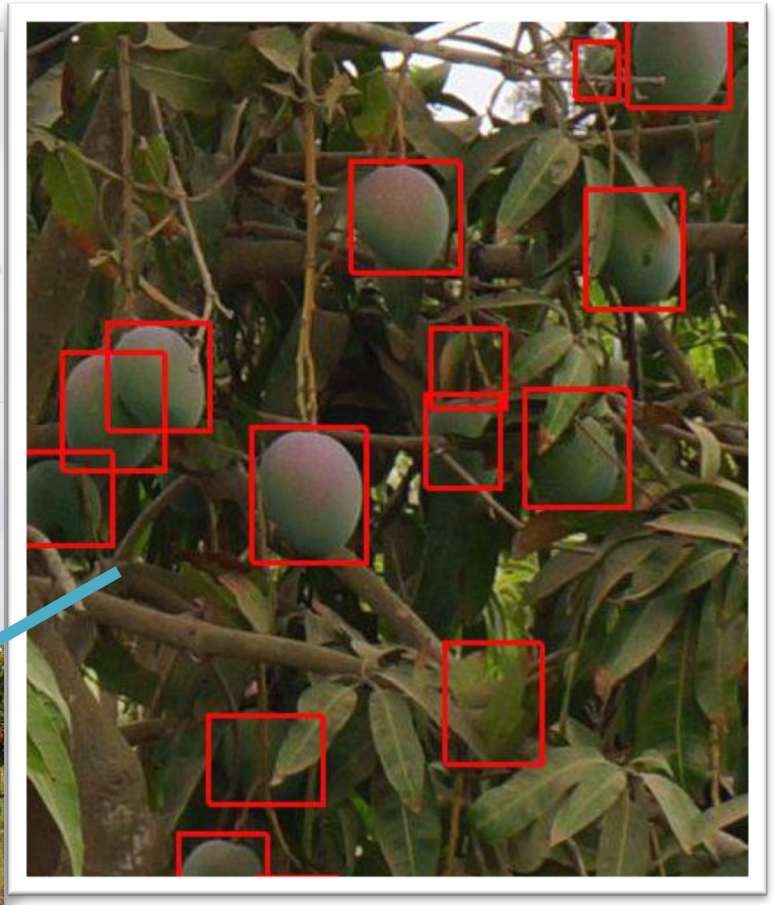
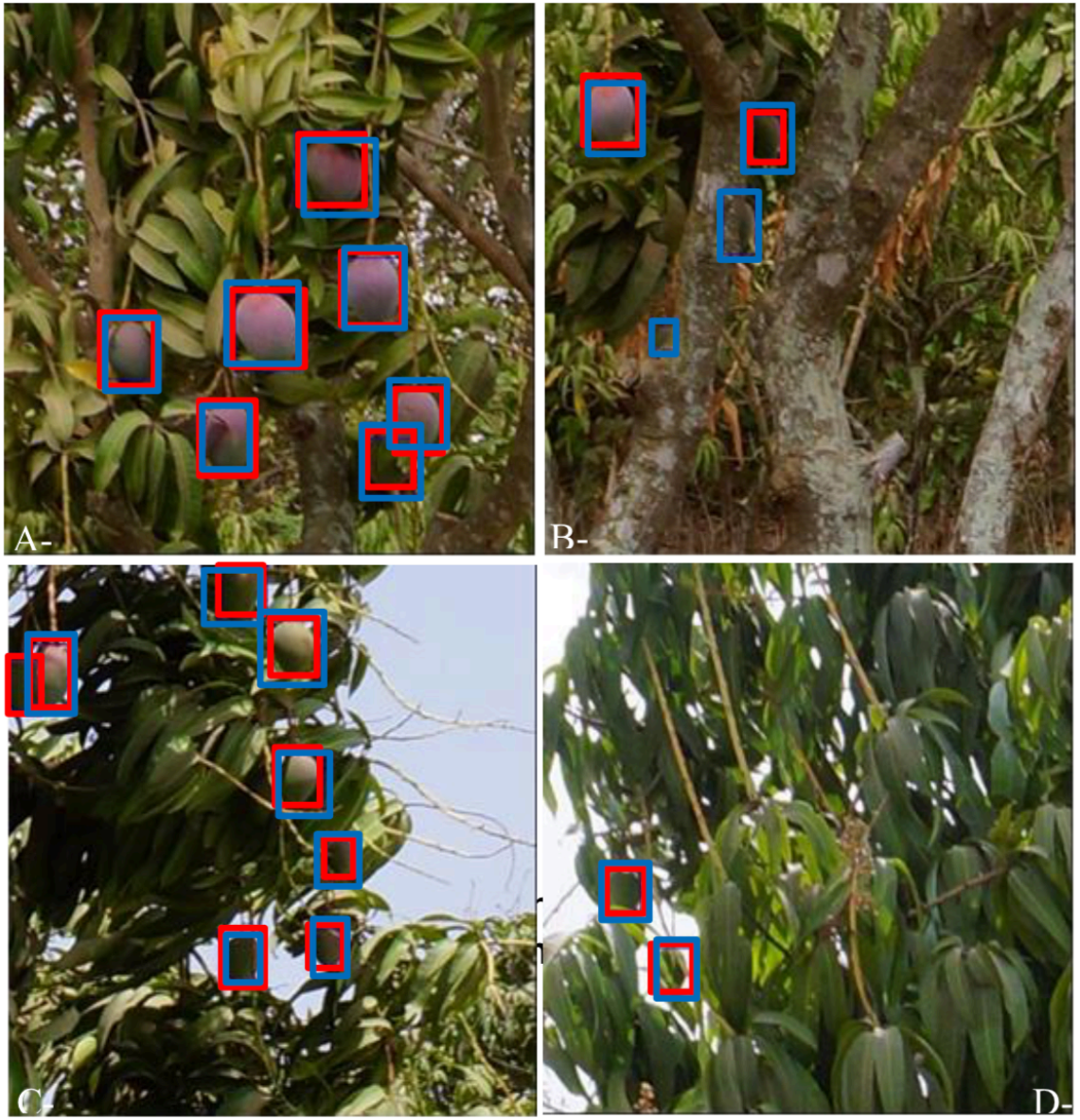
Deep Mango: quantitative results



The network detects fruits at various stages of development in very different configurations (shade, lum., saturation…).

Deep Mango: performances evaluation



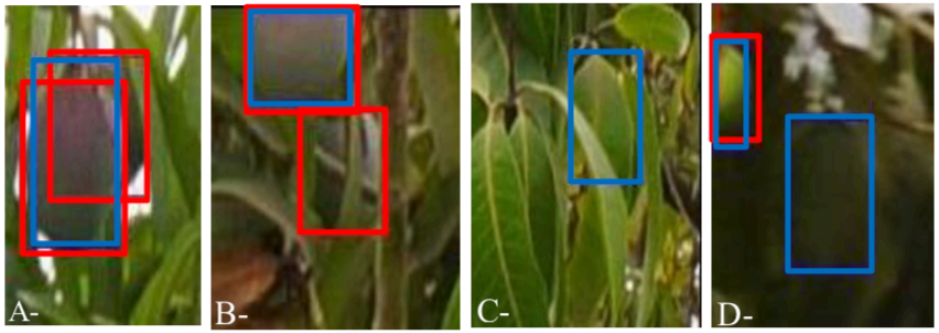
Annotations

Experts

CNN

Deep Mango: performance evaluation

1 VP | 1 VP | 1 VP



1 FN Occluded | 1 FN Hidden | 1 FP Leaf

		Référence +	Référence -
Test	+	VP	FP
	-	FN	VN

- Précision :

$$P = \frac{VP}{VP + FN}$$

- Recall

$$R = \frac{VP}{VP + FP}$$

- F-mesure :

$$F_1 = 2\frac{P * R}{P + R}$$

- **F1-Score is a measure of accuracy = 0.92**

  - Evaluation of the accuracy of fruit detection and identification by the F1-score, well suited to the statistical comparison with a real "image truth ».

  - The F1 score is the **harmonic mean of the precision and recall**, where an F1 score reaches its best value at 1 (perfect precision and recall).

DeepMangoes : hardware

- Computer:
  - Dell 7910 , 64 Go de RAM, processor Intel Xeon E5-2620 v3 (6C HT, 15 MB Cache, 2.4 GHz avec 6 cœurs et 12 threads), and graphics card Nvidia Quadro M4000 (8 GB, 1664 cœurs).
- Computational time (1 image RGB 4000 x 6000 px)
  - Traitement en mode GPU: **10 secs**
  - Traitement en mode CPU: **1 hour 28 minutes**

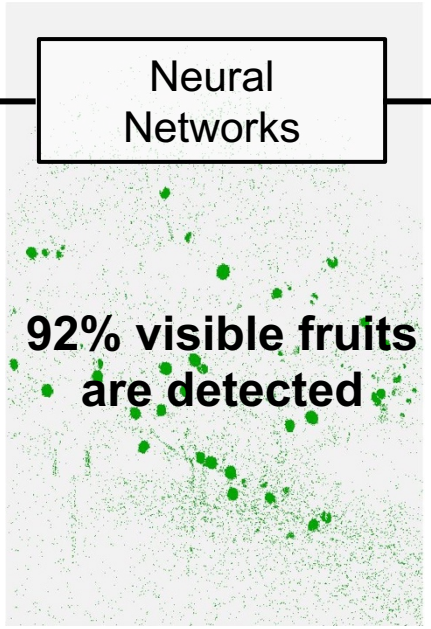
  time includes preprocessing (images) and post-processing (results) done in CPU
- Under the framework Caffe
  - dédié aux stations de travail et la mise en production
  - peut être remplacer par un environnement plus « moderne »
- Containeur Singularity
  - facilite le portage des réseaux et de leur environnement
  - Supprime les coûts de transfert de données entre le DD et le Conteneur
- only under OS Linux
  - Attention compatibilité architecture du noyau Linux

R-CNN: objectively and accurately quantify mango tree production

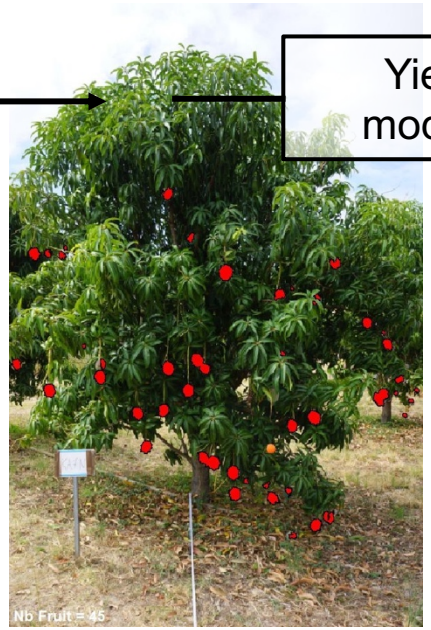
Image RGB

Deep-learning

Neural Networks

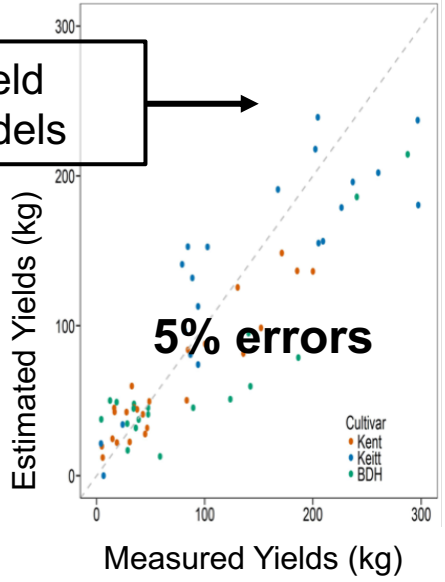


Counting



Tree Production

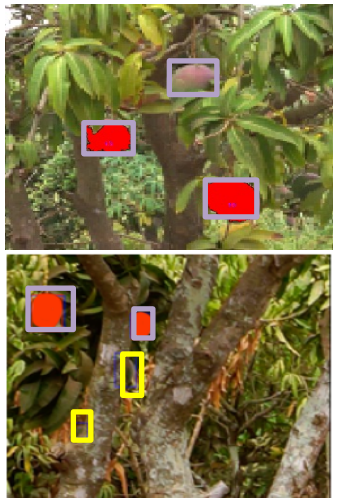
Yield models



Robust, adaptable (green fruits -> mature, 3 cultivars, lum.)

Fast (few secs / image) & accurate…

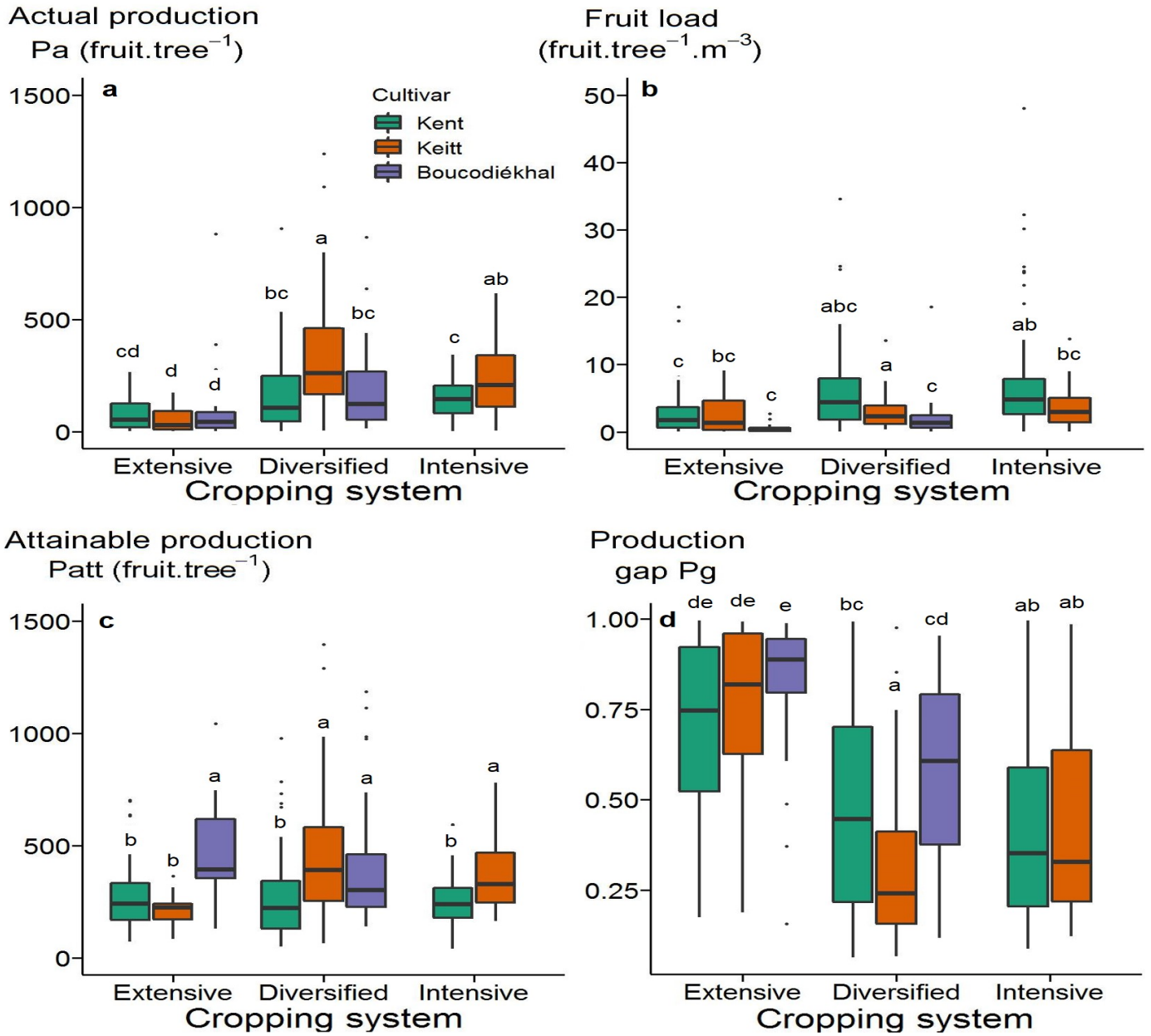
Field measure IMAGES → **Estimation PRODUCTION**



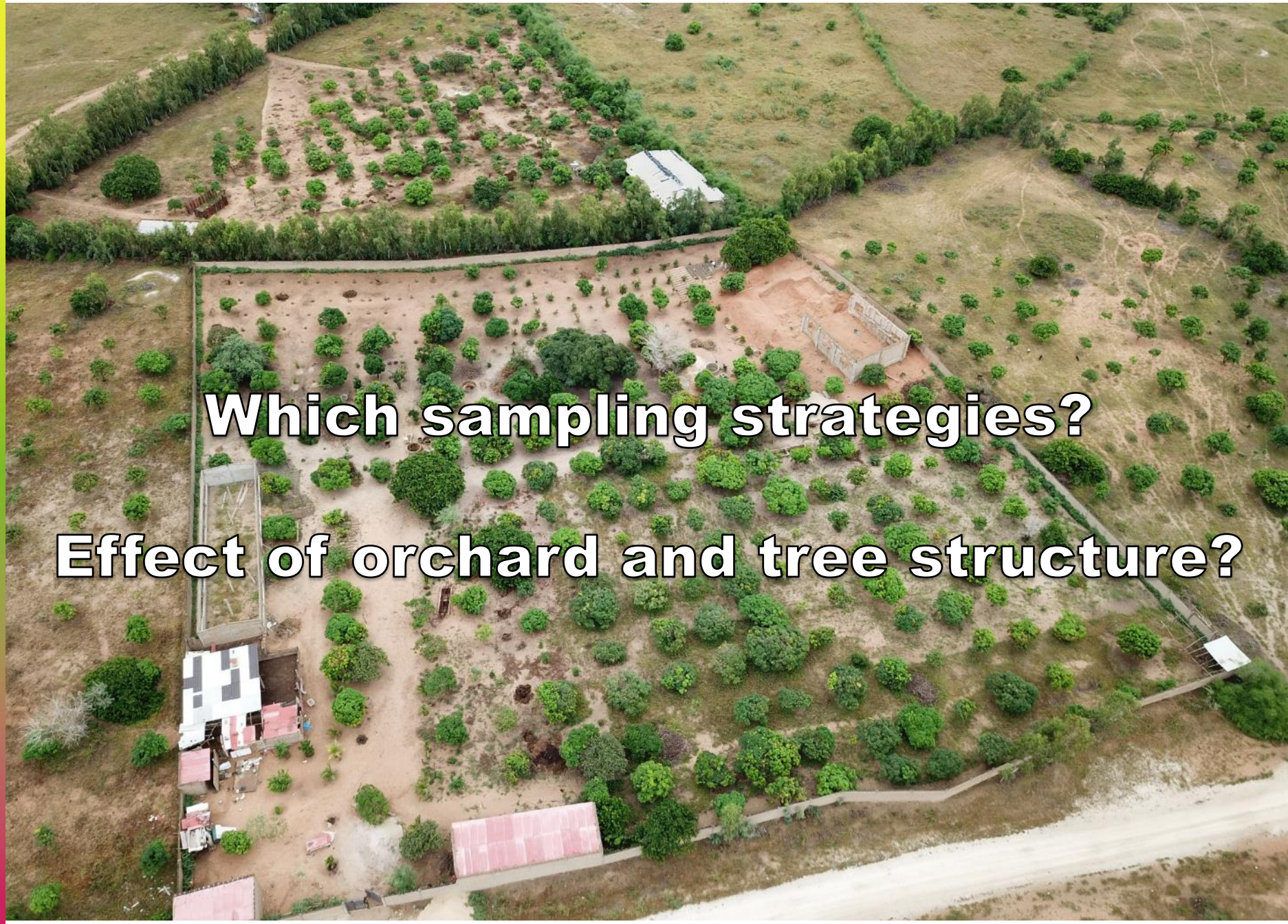
Sarron *et al.* 2018, Borianne *et al.* 2019

Yield gaps at the tree scale

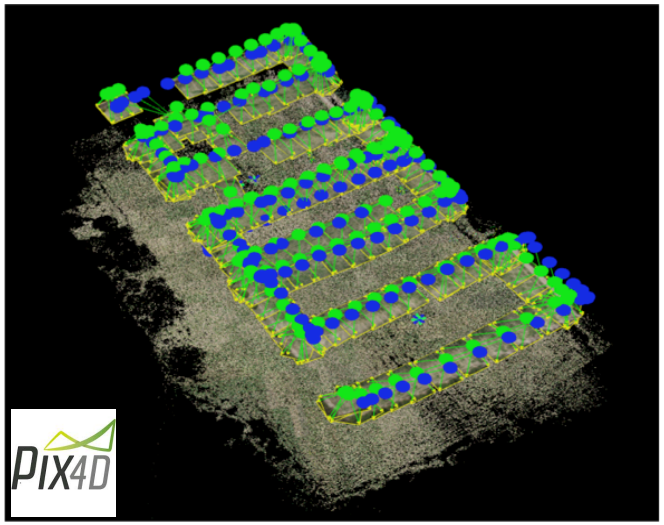
Sarron *et al.*, In press

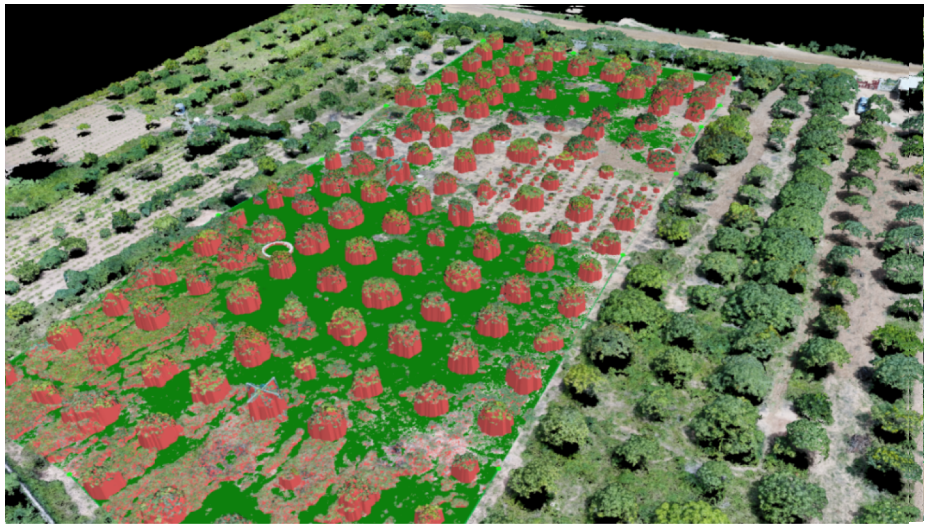


Estimating mango yields at the orchard scale



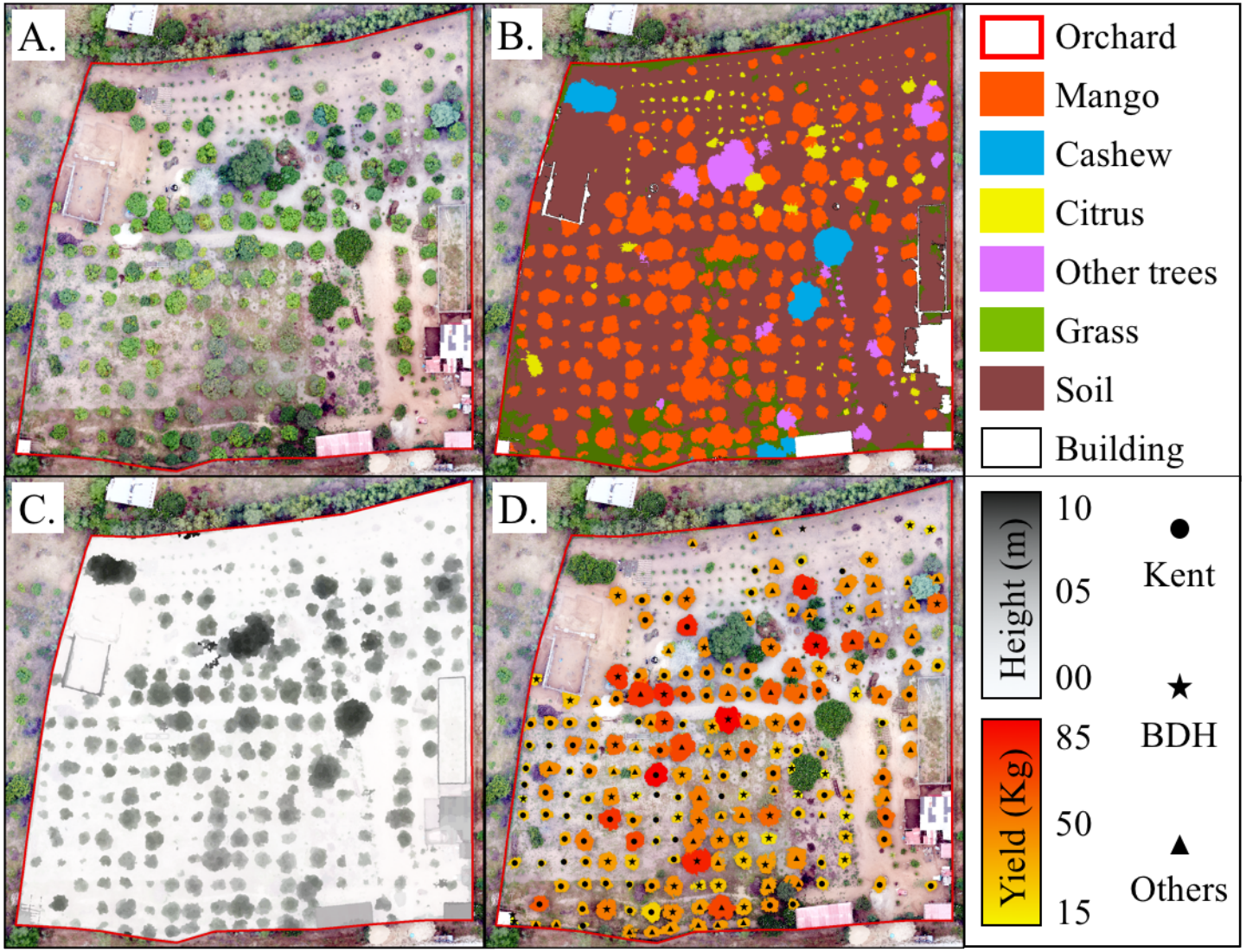
Mapping mango orchards





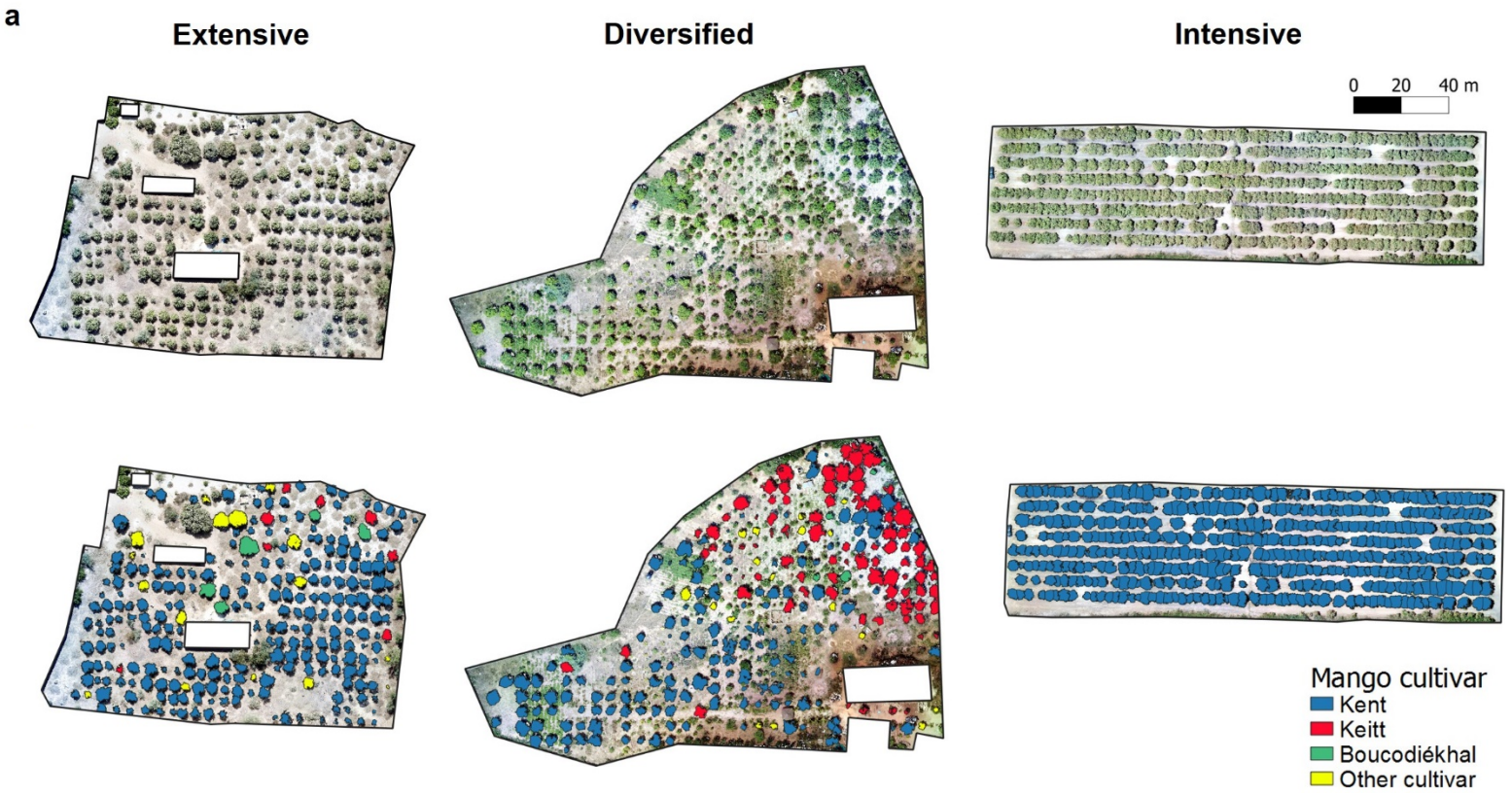
2D/3D UAV-based mapping

Land uses and structures in mango orchards



Sarron *et al.* 2018

Intrafield variability: CNN applied to all trees



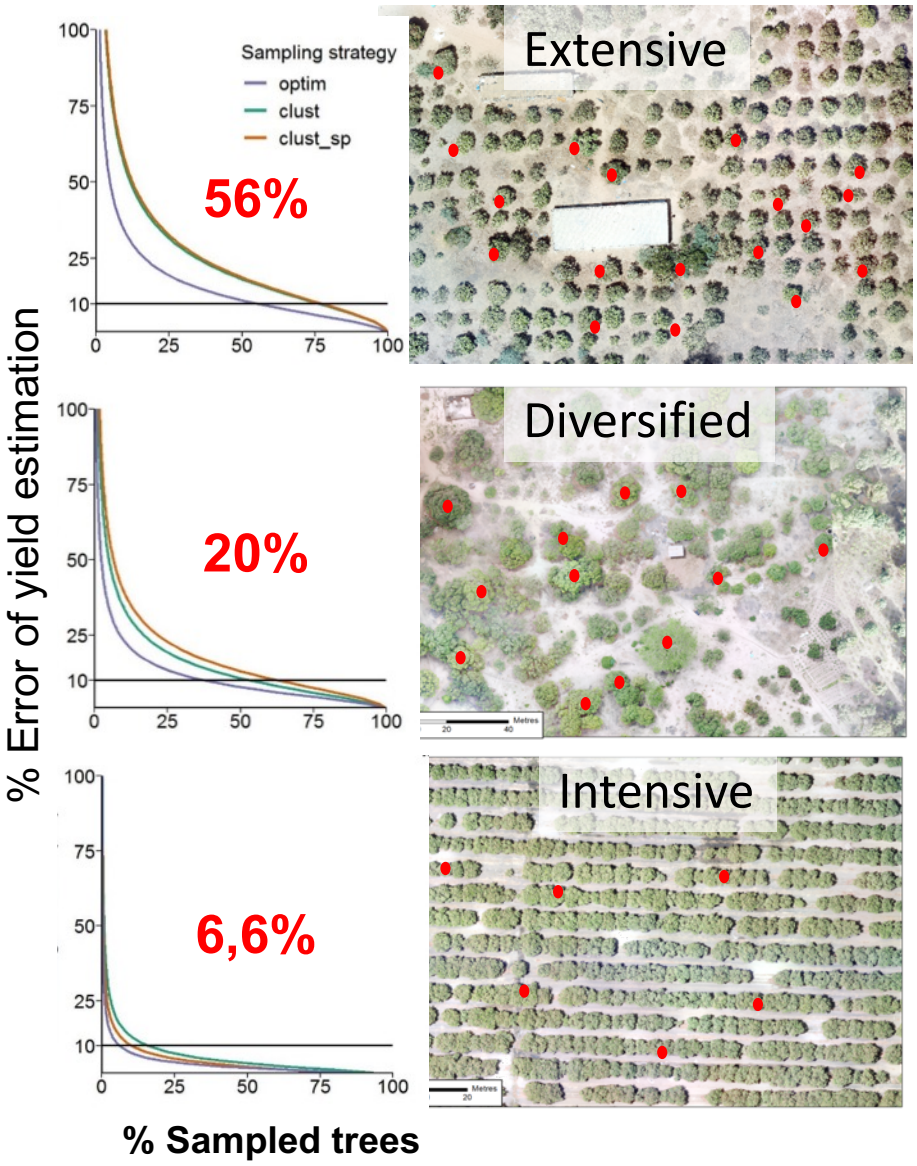
I = 0.22***

Takes days to achieve !!

7,18 tons /1,24 Ha **19,96 tons/1,52 Ha** **28,07 tons/1,20Ha**

Sarron *et al.* Sub.

Adapted sampling strategies for < 10 % errors



Orchard sampling stratégies

- Random
- Structural cluster for diversified orchards (37 to 20%)
- No spatial or cultivar clustering

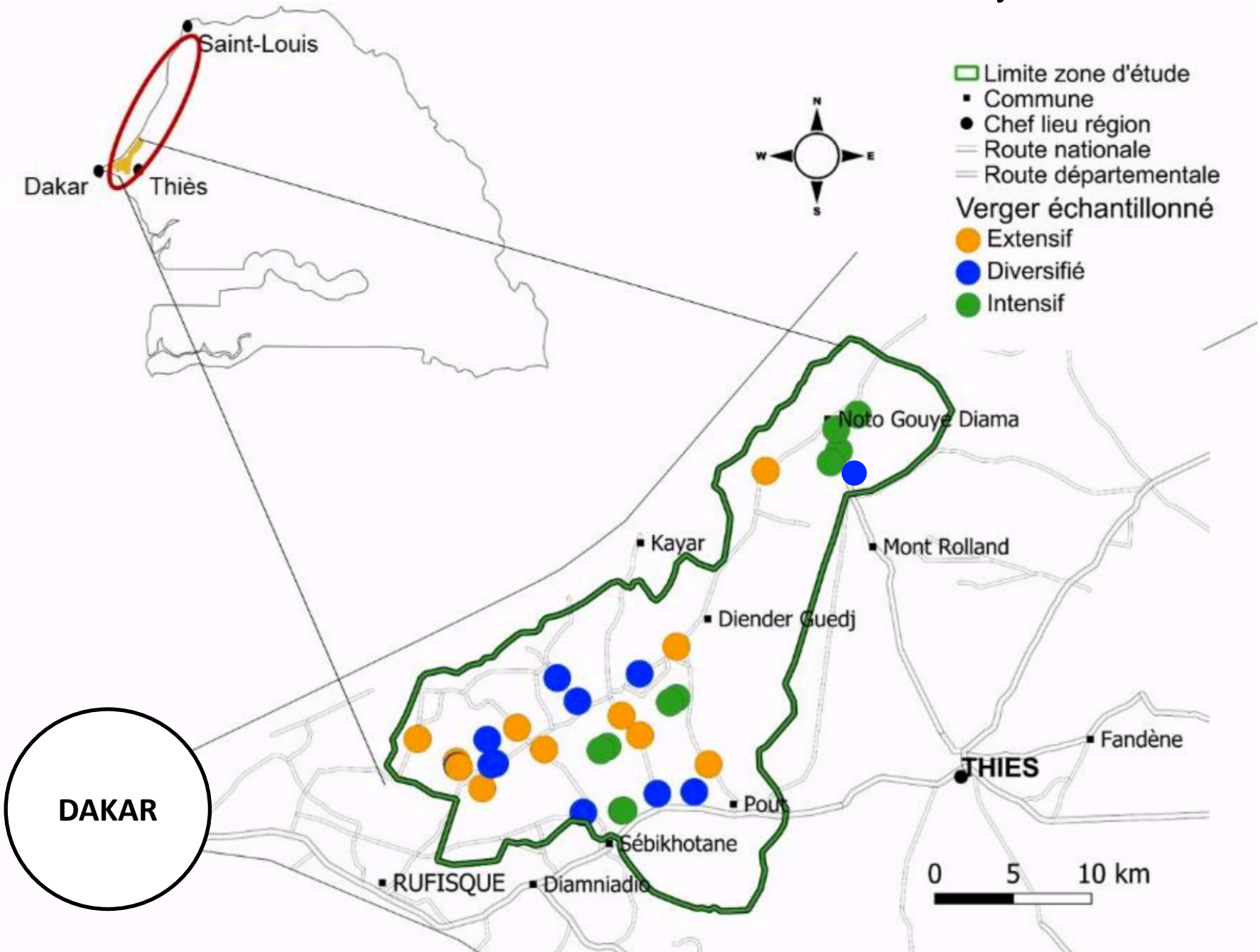
Yield estimates:

- Accurate (Cv <5%)
- Optimal sampling = to reach < 10%
- + sampled trees = - errors (4% when 100% trees sampled)

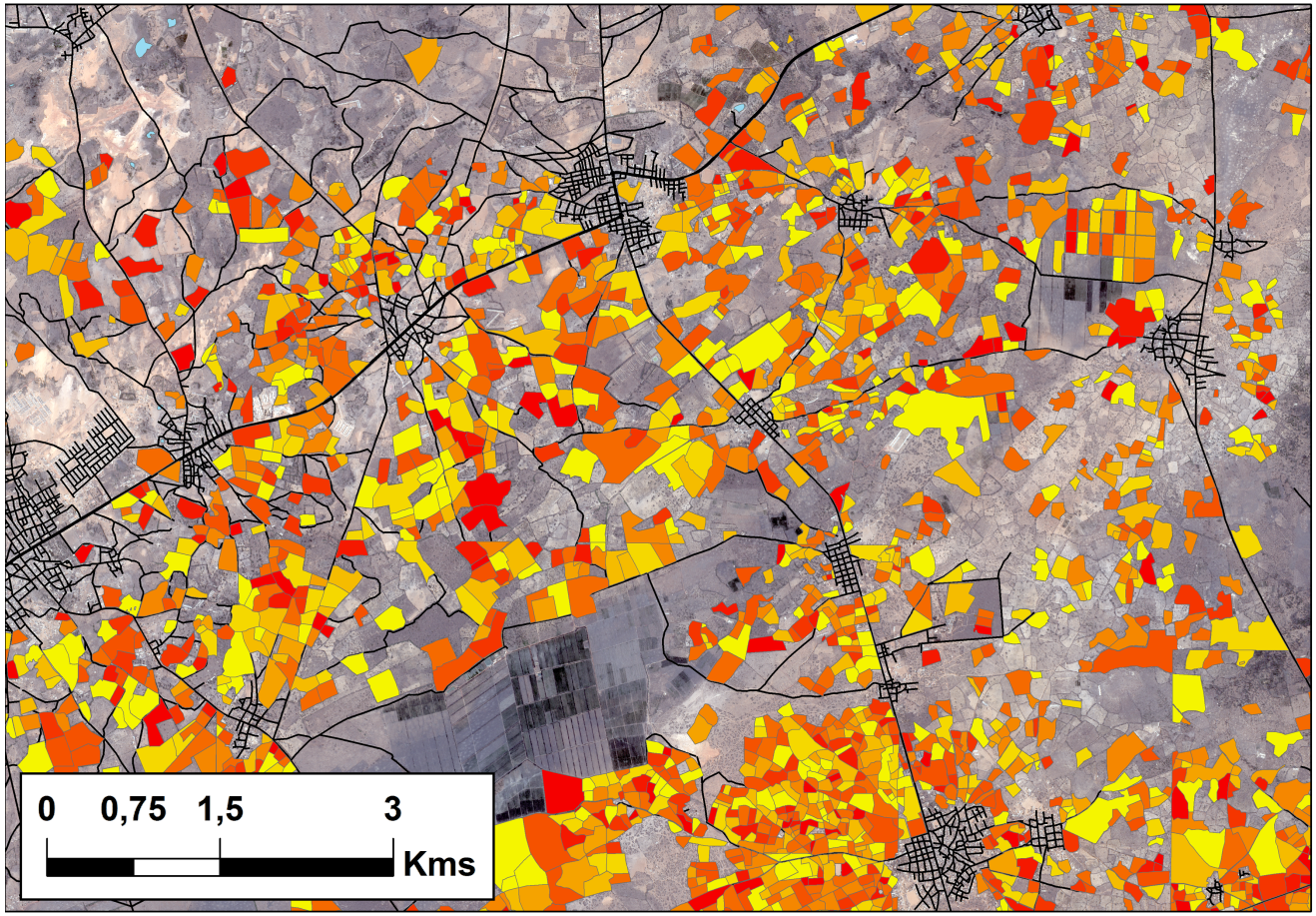
Mango production variability at the regional scale

And at the regional scale?

30 orchards with yield estimations



Finding the drivers of orchard yield variability

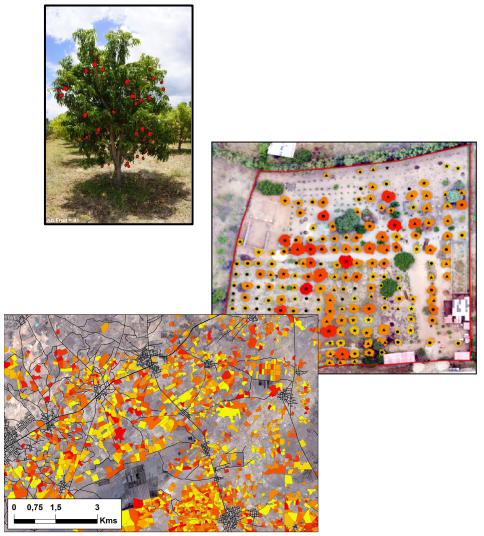


Regional diagnosis

- Orchard type
- Soil
- Climate
- Water access
- Grower practices
- Tree density
- Cultivars
- Orchard areas…

To be validated

What we have & What do we do now?



- **CNN:** accurate tool for tree production assessment
- **Sampling strategies:** => orchard yields
- **GIS Database:** orchard types, soil, climate …

Empirical models to estimate mango production

- **Tree scale:** Correctif des échantillonnages CNN par variété

Tree Model	Tree Prod. ~ Cultivar + Nb fruits CNN (2 pics)

- **Orchard scale:** extrapolating the sampled tree productions

Orchard Model	Orchard Prod. ~ Type + Structure + Site + Sampled tree production

- **Bassin scale:** applications sur carte des type de vergers par satellite

Bassin	Prod. Bassin ~ Tree density + % Cultivars + Site + Type + Yields of the nearby sampled orchards

PixFruit plateform

Building a **participative** and **digital data manager** for multi-scale estimations of **fruit tree productions** to address the needs of the stakeholders of the **fruit value chains**.

PixFruit's team

Philippe Borianne
Neural Networks
Data Science

Julien Sarron
Machine vision
Yield modelling

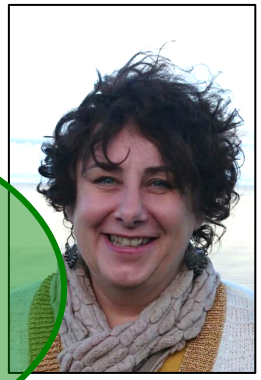
Emile Faye
Agro mango
Value chains
DigitAg

cirad

PixFruit

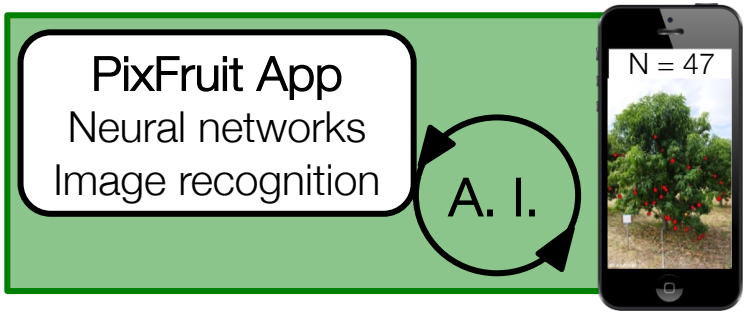
Mangue

Hamza R. Chaham
COO
SOWIT



Véronique Henri
m-Agri
Design thinking
orange™

PixFruit App

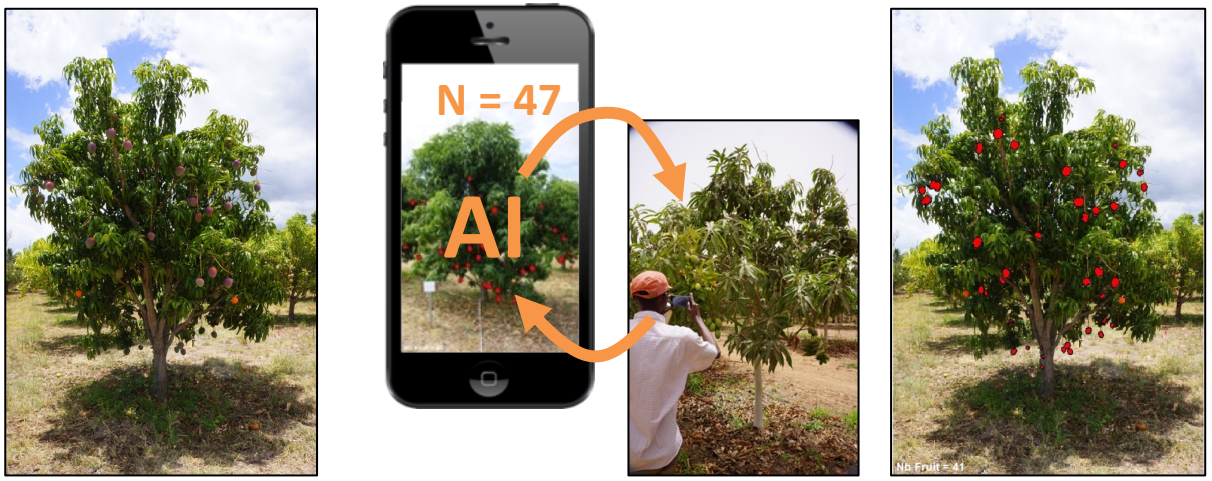


Real-time information tool on tree production

A participative sampling tool

to quantify objectively, accurately and instantaneously

the production of mango trees



Implementing a Yolo CNN with TensorFlow on Android & IOS

PixFruit App

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Image recognition

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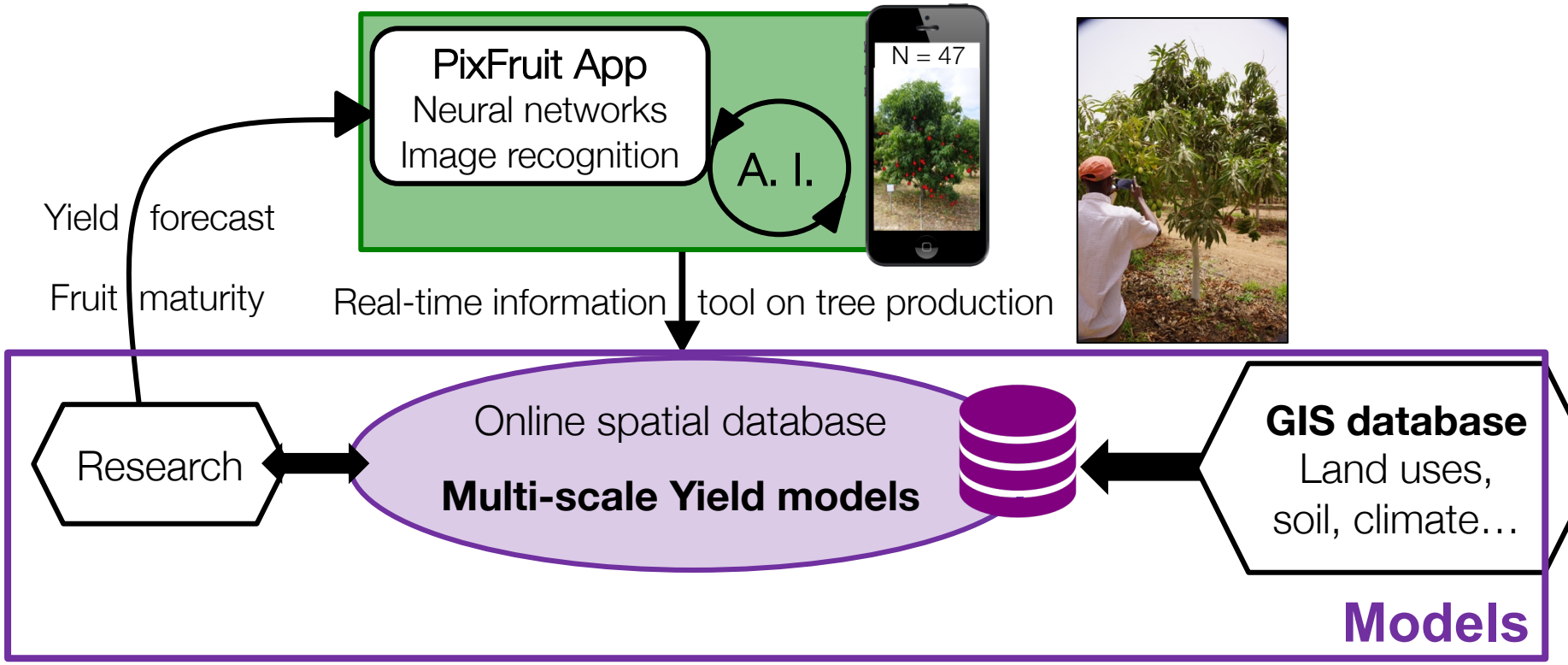
Real-time information tool on tree production

Tree Model

- **Tree cultivar and nb of fruits**
- GPS loc., time, date of acquisition
- User profile (name, profession, age..)
- Orchard data (%cultiv., area, density…)
- (Images if wanted)

Orchard Model

- **Current orchard yield (tns/ha)**
- **Production per cultivar**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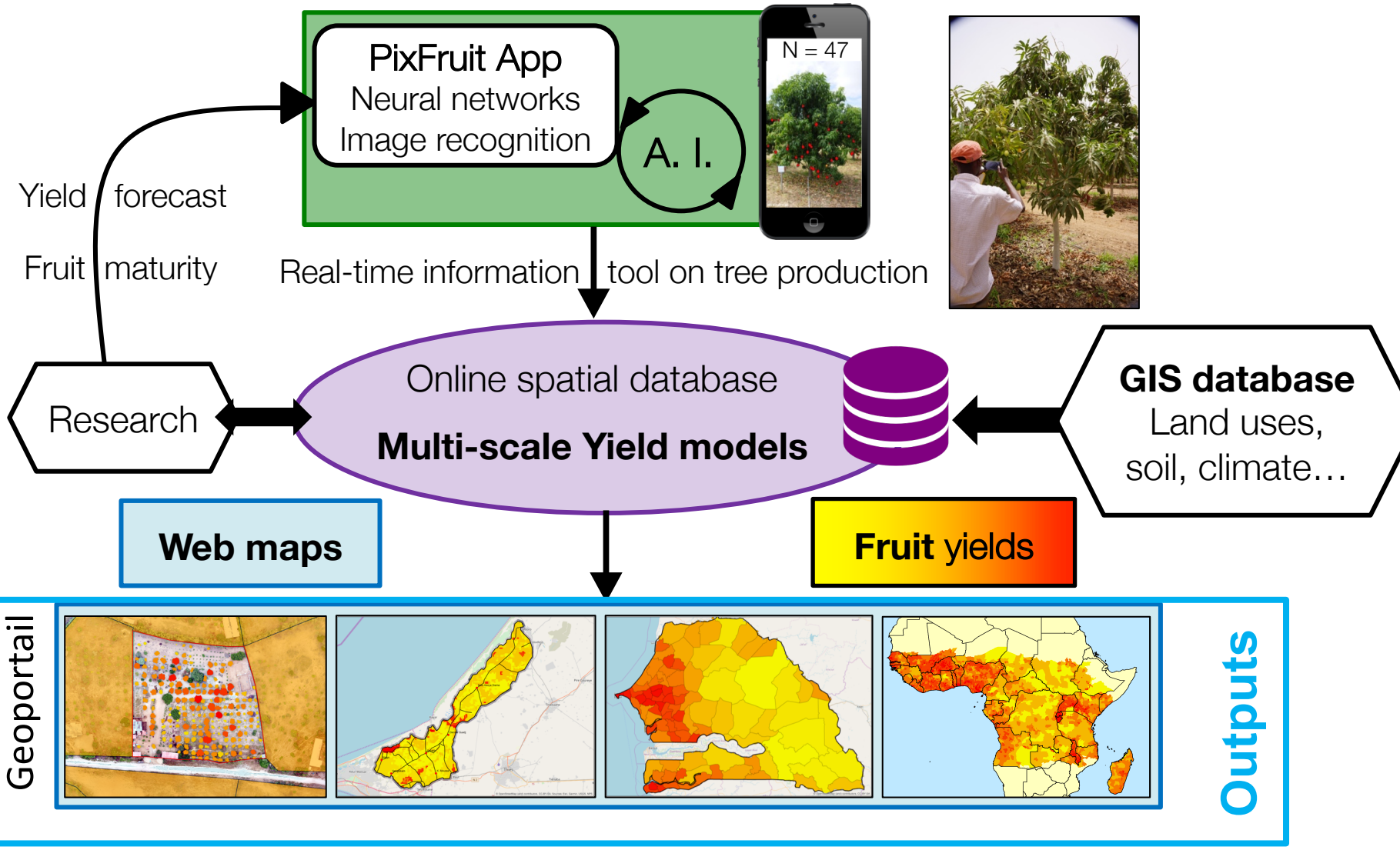
Fruit maturity
Real-time information
tool on tree production
Research
Online spatial database
Multi-scale Yield models
GIS database
Land uses,
soil, climate…
Models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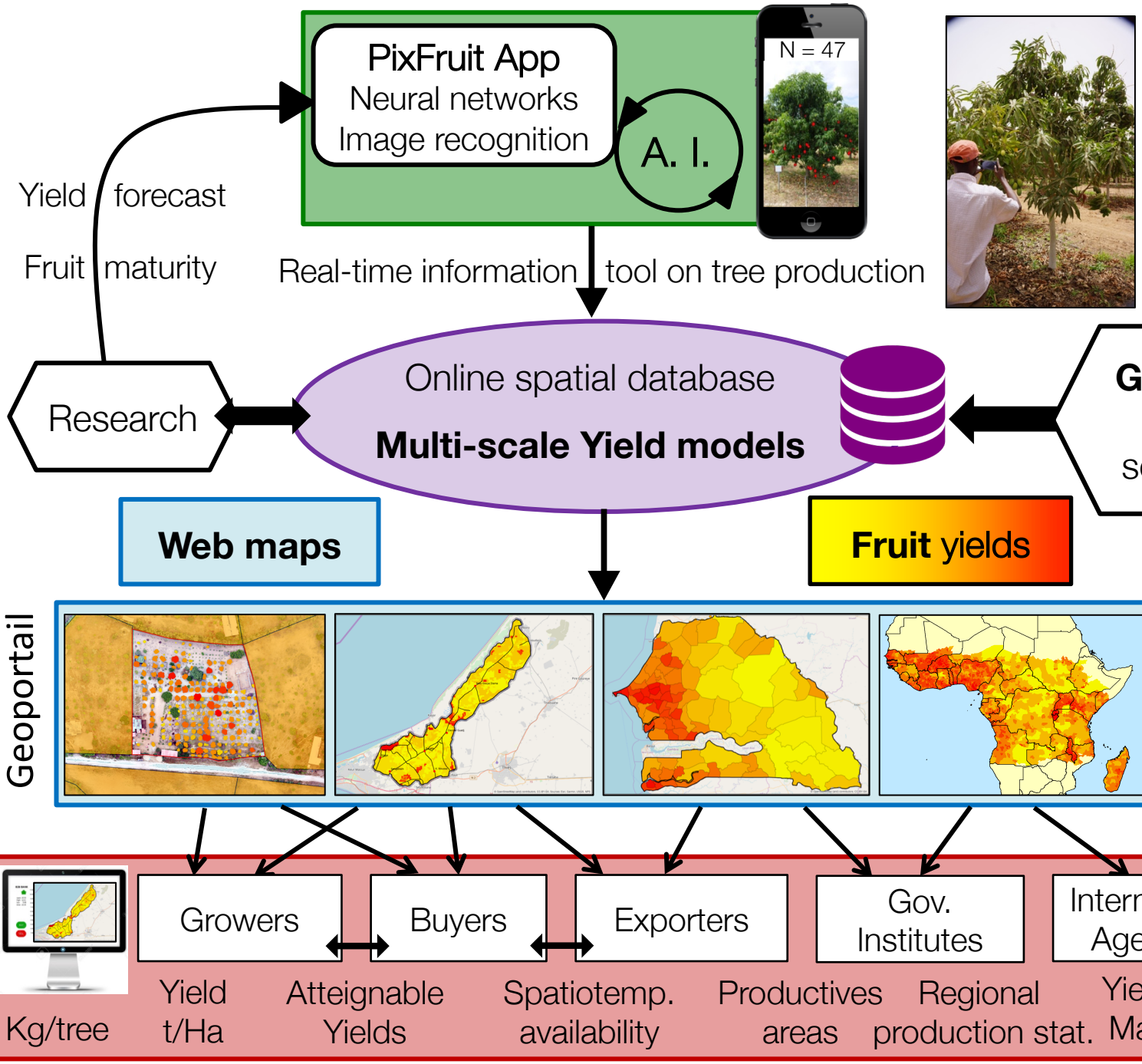
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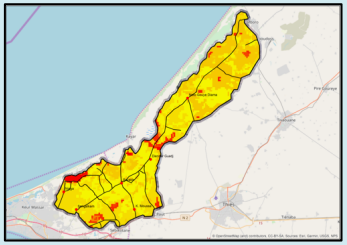

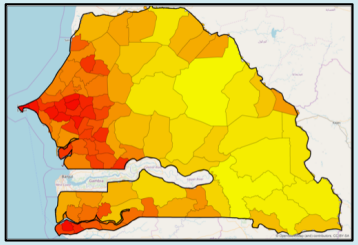

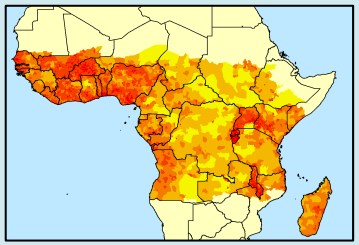

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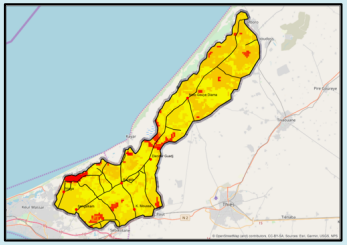

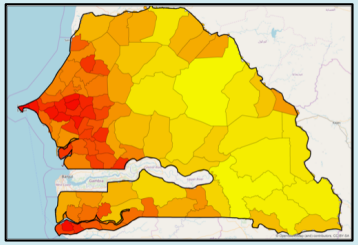

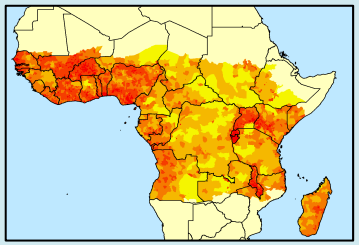

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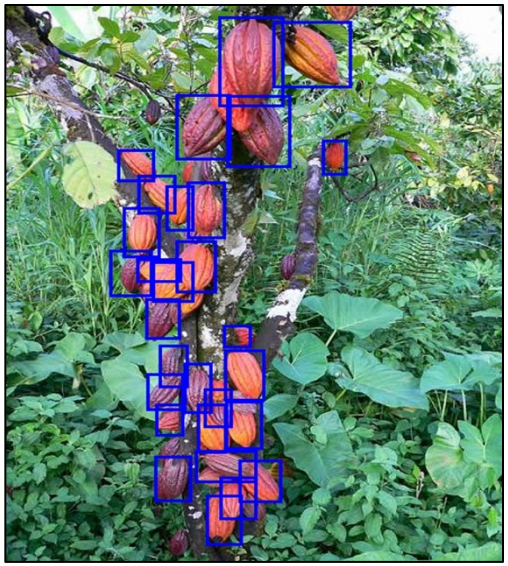
Pixfruit, next steps

- July 2020: release PixFruit App *v. beta*
- Ending 2020: prototype Senegal, Ivory Coast (Maroco, Haiti
- Towards forcasting Havest & Maturity
- Diversification

Litchi

Cacao



Citrus