The European Commission's science and knowledge service

Joint Research Centre

Estimation of crop residue production in Europe with empirical models

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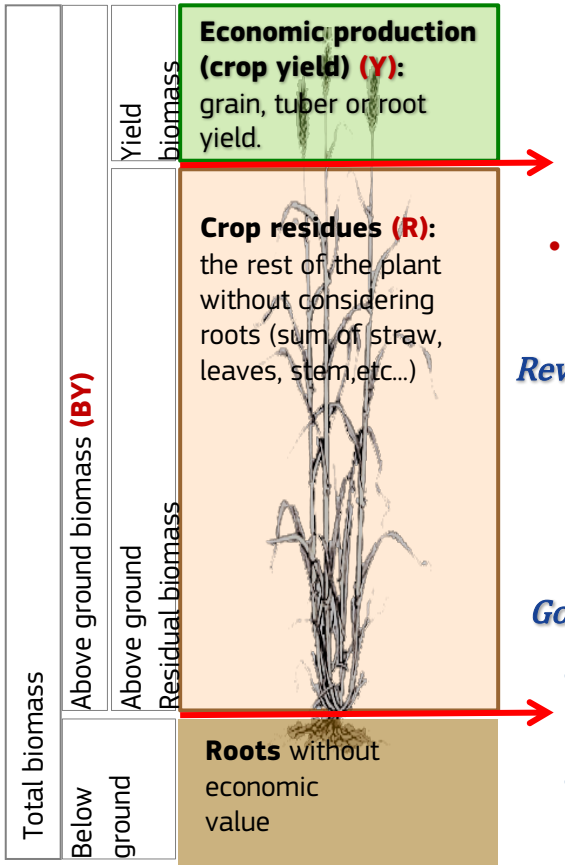
Context

Objective, assessment approach, state of art, knowledge gaps

*Objective: **quantify** and **spatialize** the **current biomass** production from agriculture in Europe without considering final uses*



Biomass (BY)

Y **:** available statistics
R **: PART TO ESTIMATE**

Approach for assessment:

- **Infer crop residues (*R*) from crop yield (*Y*) statistics:** used in large-extent assessments of biomass potentials.
  - **Through** coefficients (biomass partitioning) like the **harvest index (*HI*)** or the residue-to-product ratio (*RPR*)

$$HI = \frac{Y}{Y+R} = \frac{Y}{BY} \qquad RPR = \frac{R}{Y}$$

Review of similar studies :

- Constant crop-specific *HI* coefficient (or *RPR*).
- Empirical regression models (e.g Log,Exp), assuming + correlation *RPR*(*HI*) and *Y* (e.g. Scarlat et al. 2010, Bentsen et al. 2014).

Going further...faced questions:

- Do **positive relationships** between ***HI*** and ***Y*** **exist**? Is the nature of that relationship **similar for all crops?** Agronomic **reasons** behind this?
- How much **uncertainty** can we expect when estimating **crop residues** using such empirical models?
- How can model estimations and uncertainties **influence** the assessment of residues production **at EU28 level**?

Global Objective
Questions+Mandate+Comparison

Methodology – Part 1: Creating empirical models

Collection of experimental data from scientific literature

Extensive literature review of papers in English reporting **experimental data on economic yield and biomass partitioning** (*HI*, harvest index)

From a first selection of about **120 papers**, extracting ***1580 observations*** based on their definition of *HI*.

Yields were **transformed to dry-matter content**

Number of observations used per geographical area

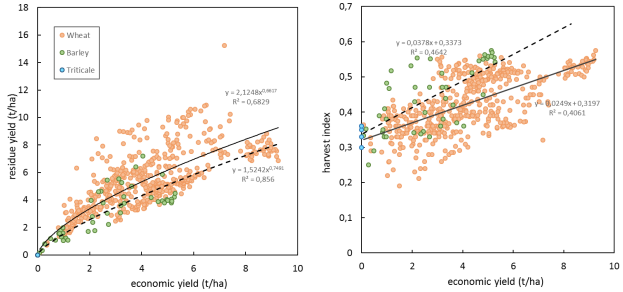
Geographical region\Crop	wheat	barley	maize	rice	sorghum	rapeseed	soybean	sunflower	potato	sugar beet	**Total Regions**
EU-28	200	13	23		6	82	12	4	40	19	**399**
Europe (others)	10										**10**
North America	86	12	115		15	8	54		6		**296**
South America			46						18		**64**
Middle East	36	12	16			100		34		26	**224**
Southern Africa	9										**9**
Southern Asia	56		45	20	69			32			**222**
South-eastern Asia				59			29				**88**
Eastern Asia	40			52		34	18		8		**152**
Australia	66	4			38						**116**
Total Crops	**503**	**41**	**245**	**131**	**128**	**224**	**113**	**78**	**72**	**45**	**1580**

Methodology – Part 1: Creating empirical models

1) FINDINGS ABOUT: Nature of the relationship between *Y* and *HI*

Groups of crops with **2 different behaviours in the relationsip *Y-HI***

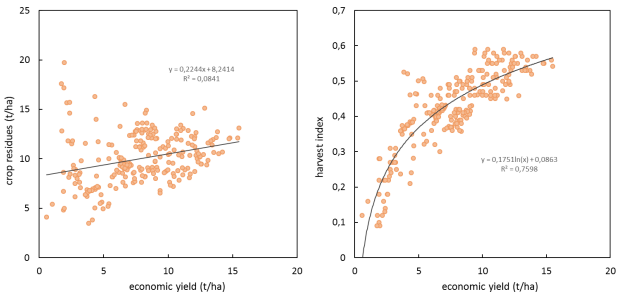
Wheat, barley, rice, sunflower, rapeseed



- ***Y*** and ***R*** are **strongly correlated**
- Consequently, ***HI*** is **stable**, and **weakly correlated** with ***Y***

In these crops, kernel number is determined during vegetative growth (tillering, heading phases), which makes final yield correlated with vegetative biomass

Maize, sorghum, soybean, potato and sugar beet



- ***Y*** and ***R*** are poorly **correlated**
- Consequently, ***HI*** is variable, and **strongly correlated** with ***Y***

In maize and sorghum, both kernel number and grain weight are after the plant vegetative growth

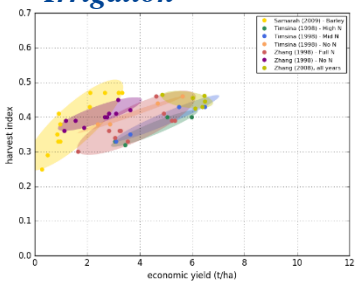
Potato and sugarbeet vegetative biomass is detached from yield

2) FINDINGS ABOUT: How *Y* and biomass partitioning (*HI*) are affected by the influence of environmental/genetics/management

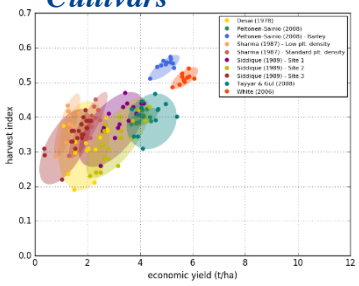
Irrigation (water availability) introduces significant **changes** in both ***HI*** and ***Y***

Genetics introduce **variability in *HI*** but not too much in *Y*. **N** fertilizing **changes *Y***, but not the HI

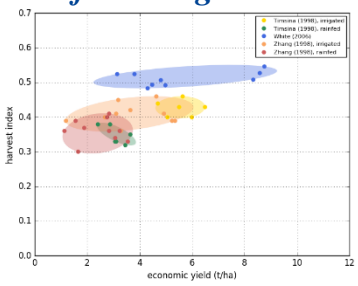
Irrigation



Cultivars



N fertilizing



Therefore, **empirical models** between ***Y*** and ***HI*** are mainly **describing changes in water availability**

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Methodology – Part 1: Creating empirical models

3) Producing new empirical models to predict R from Y with 95% confidence intervals

FINDINGS

Statistical analysis to construct robust regression models

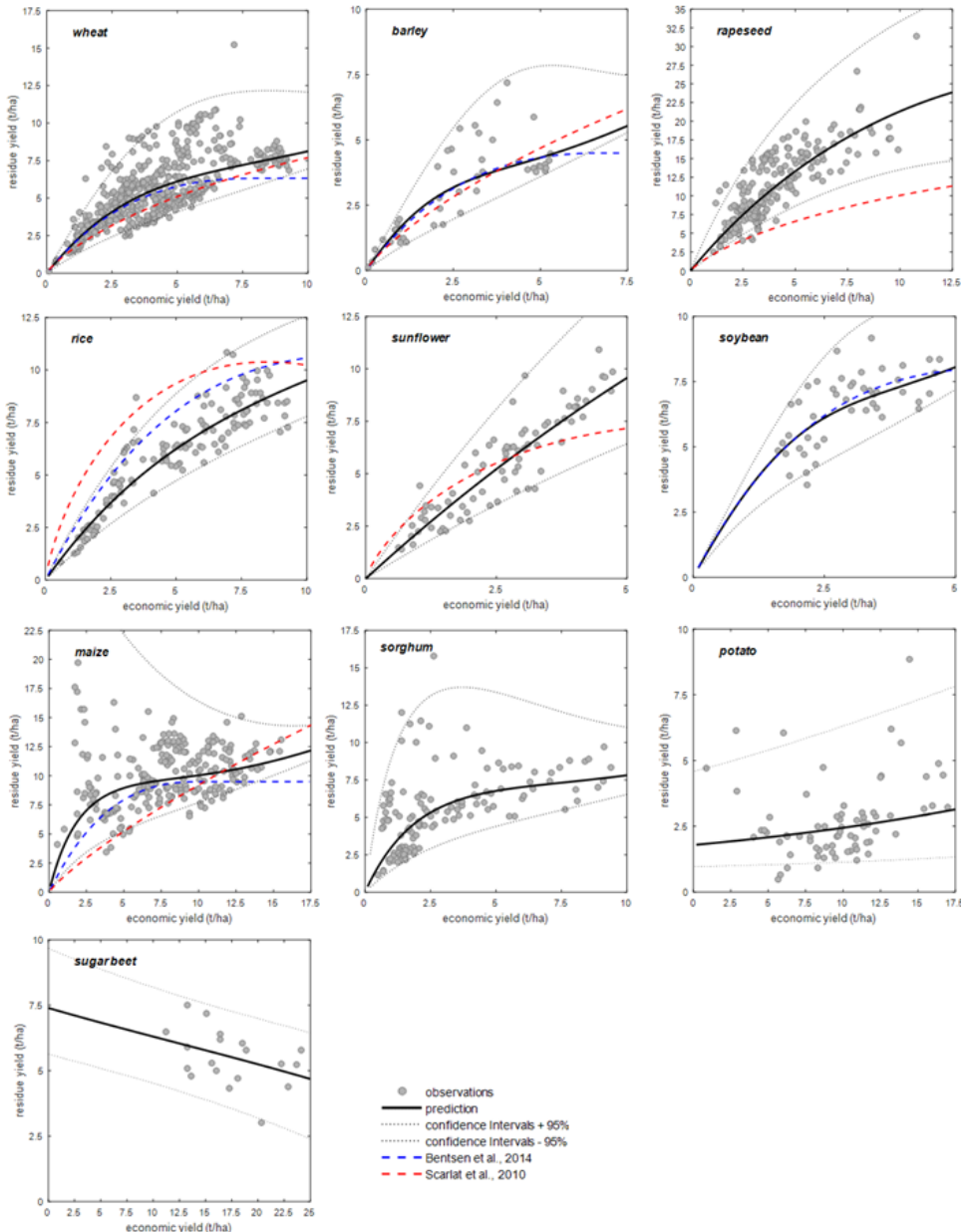
- **Finding:** Need of **using *HI* as predicted variable** to remove heteroscedasticity (R-Y) when computing models.
- Apply **transformations for normality** of residuals

Model **uncertainties** are **quite large** (e.g maize). Mostly due to differences in the crop varieties and other management factors (N fertilizing)

Overall agreement with **other studies** in the **main crops** (wheat, barley, maize).

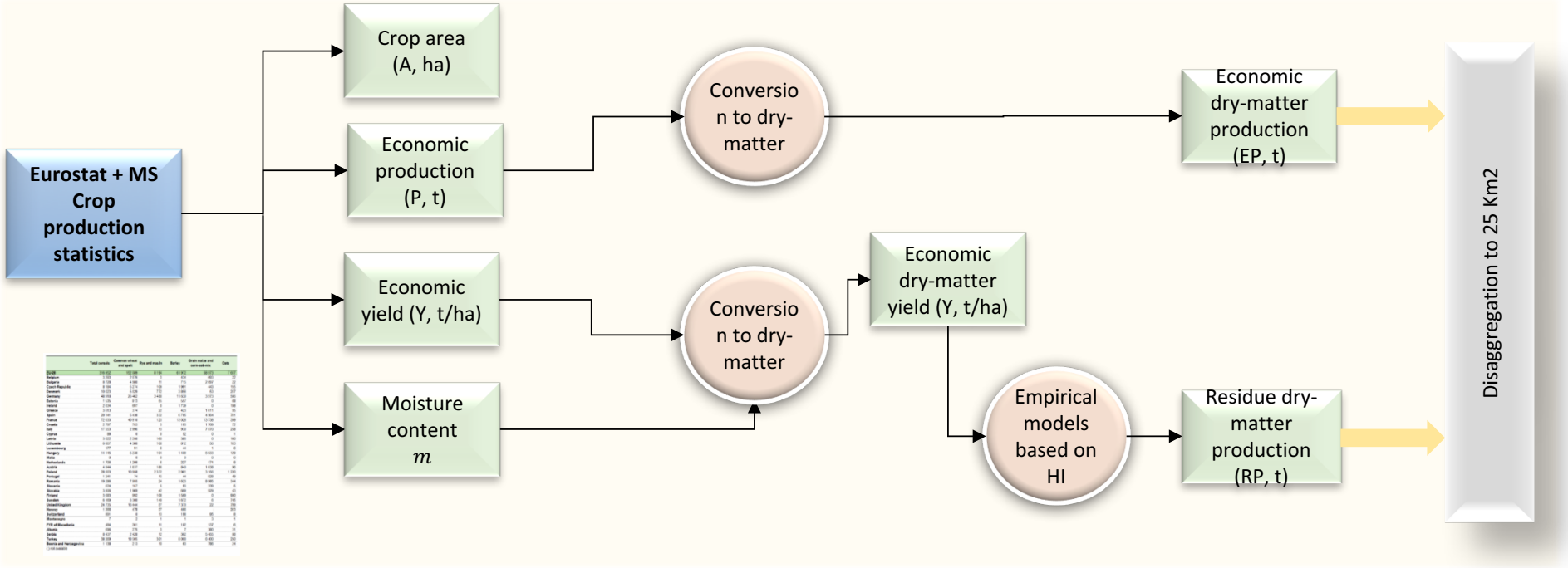
- Sometimes the differences against Bentsen et al. (2014) or Scarlat (2010) are due to the models imposed (e.g. logarithmic, exponential)

Crops modelled cover 98% of EU28 crop residue production.

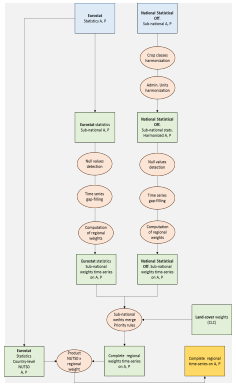


Methodology – Part 2: Assessment in Europe

Implementation of the models within EU28 and estimation for the minority crops



Collection and harmonization of regional statistics (1998-2015)



Database from EUROSTAT and MS collected at regional data (NUTS3 level)

Post-processing algorithm to generate a complete dataset

Estimation in dry matter at NUTS3 level

Economic production

Crop residues

Models: Cereals, oilseeds, sugar and starchy crops. (98% EU28 RP)
Fixed coefficients: permanent crops, (others: pulses, industrial)

Vegetables, fodder crops, energy crops

Disaggregation 25 km2

Land cover data (CLC)

$$B_g = \sum_i^n B_{c,i,N=3} * \frac{L_{g \cap i}}{L_{i,N=3}}$$

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Results – Big numbers (Dry matter Mt)

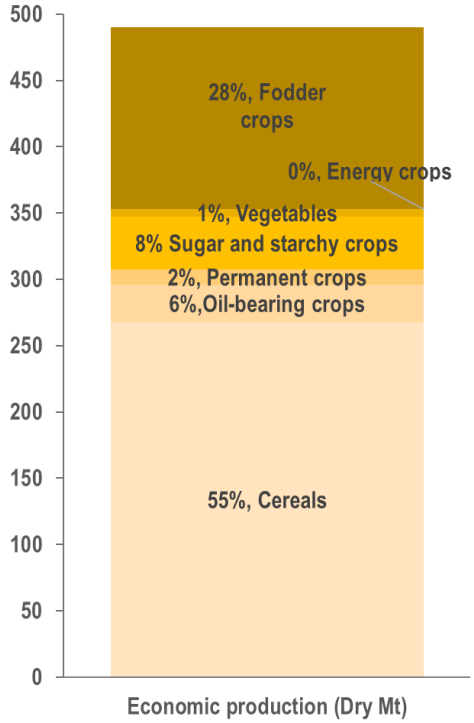
Crop group	Total Biomass	Economic production	Residue production	Upper CI	Lower CI
Cereals	609	268	341	643	227
Energy crops	0.19	0.19			
Fodder crops	137	137			
Oil-bearing crops	104	28	76	131	50
Permanent crops (+ others)	18	12	6		
Sugar and starchy crops	55	40	15	22	13
Vegetables	6	6			
Total	**929**	**490**	**439**	**796**	**290**

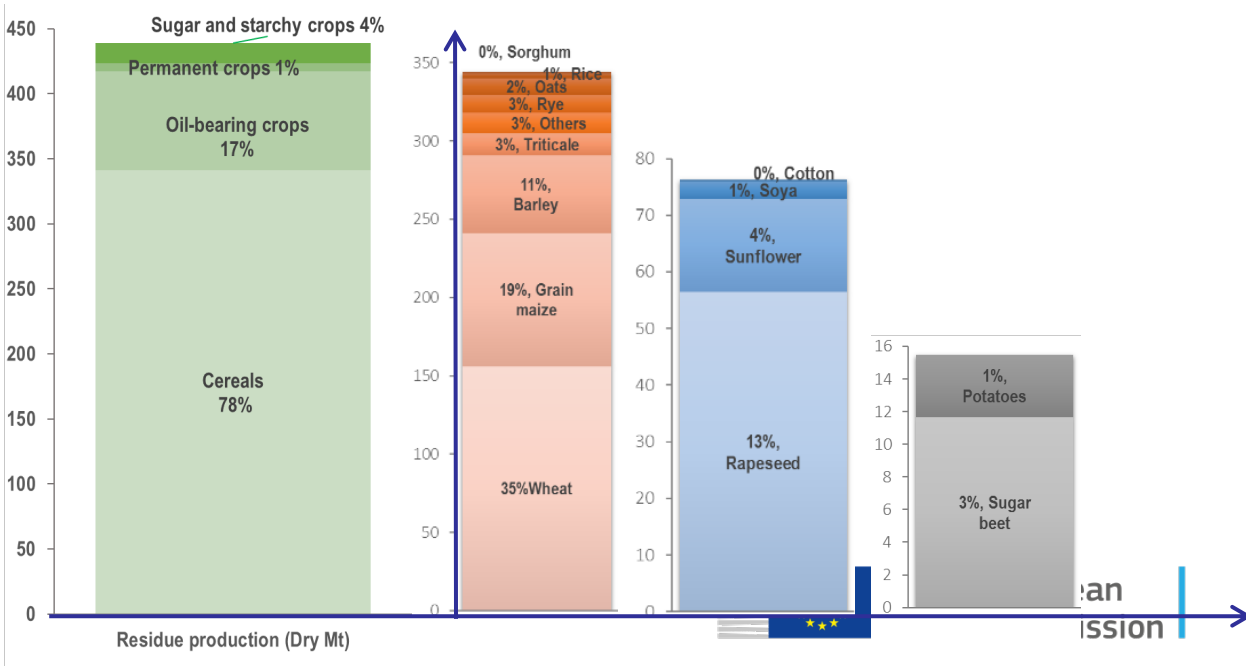
Biomass production

Economic production : (Y)

Residue production : (R)

Average (2011-2015)

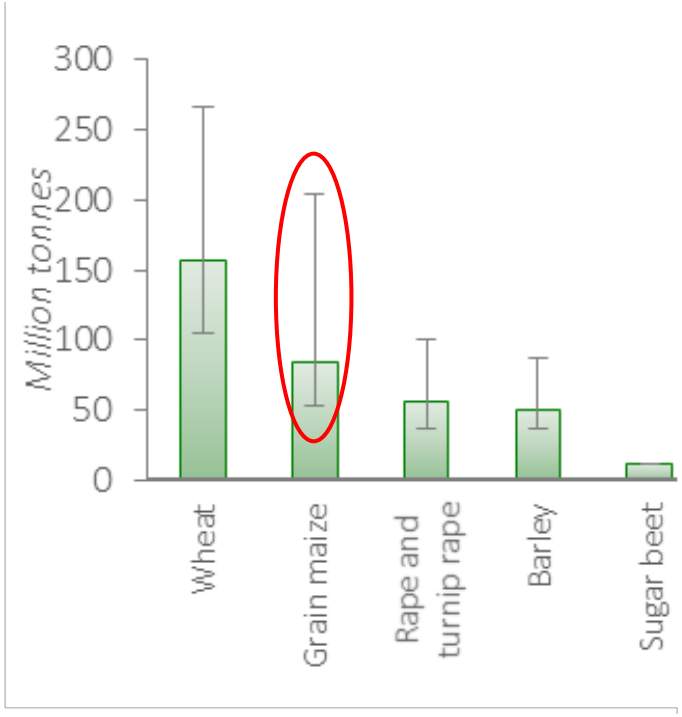


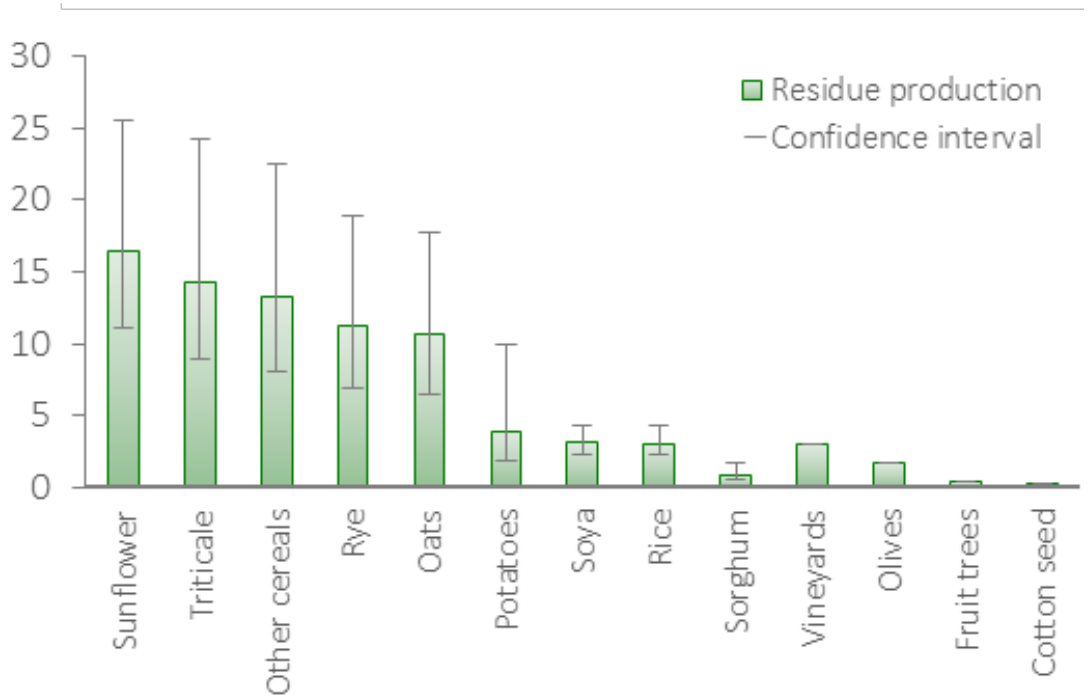


Results – Uncertainties of estimations by crops

The **uncertainties of the estimations in EU28 are high**, especially for maize, the second in importance

Mostly due to differences in the **crop varieties** and other management factors (**N fertilizing**) in the **data collected** since they are coming from experimental conditions.





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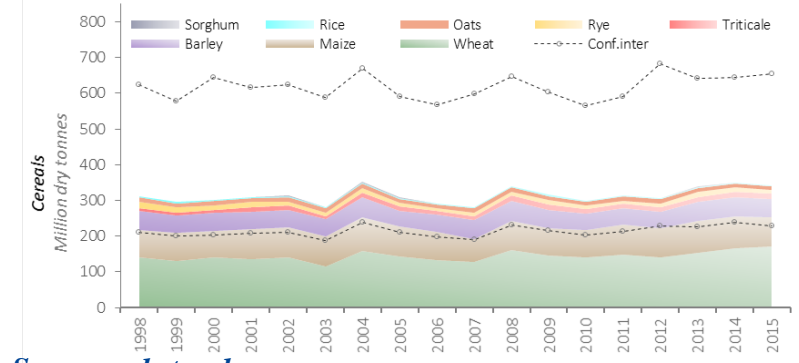
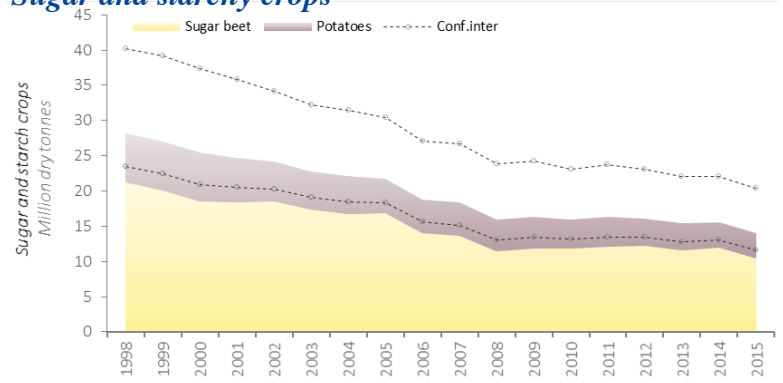
Results – Evolution and distribution in Europe

Evolution of crop production (1998-2015)

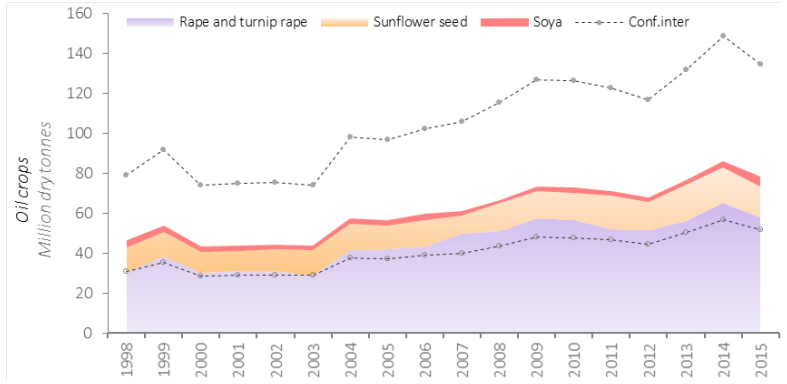
Cereals



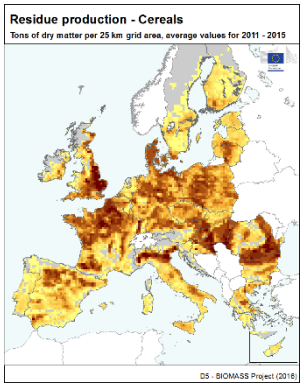
Sugar and starchy crops

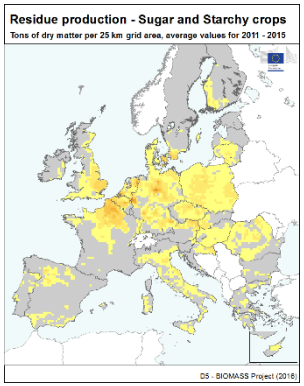


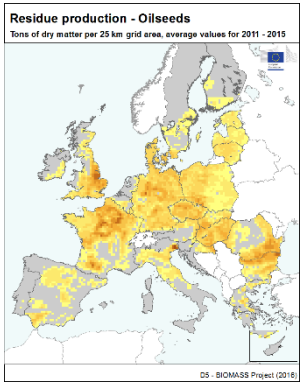
Oil crops



Current estimations (avg 2011-2015)







Tons of dry matter per 25 km grid per year

< 500	15,000 - 30,000	75,000 - 100,000
500 - 5,000	30,000 - 45,000	100,000 - 150,000
5,000 - 15,000	45,000 - 60,000	150,000 - 200,000
	60,000 - 75,000	> 200,000

Stable production

Production of residues **evenly distributed** across EU28

Inter-annual **variability** is driven by **weather**

Decrease of residue production, driven by a progressive **reduction of areas** (e.g. impact of EU-policies in the case of sugar beet (EU sugar production quotas))

Production mainly concentrated: **FR, DE, UK**

Progressive augmentation, driven by an increase of **rapeseed area**. Consequence of the **increasing use as biofuel** (e.g. after biofuel EU-policy).

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Conclusions

A relationship between *Y* and *HI* exists in the crops studied **BUT**:

- **It varies significantly depending on the crop**, and is mainly **describing effects of water availability.**
- A regression between *Y* and *HI* seems a priori of little use: **when *HI* is correlated to yield *Y*, *R* tends to be constant.**
- ***HI* is only useful** as predicted variable **to solve problems of heteroscedasticity.**

Empirical models produce **high uncertainties**, and biophysical models (EO data) are needed to reduce these **large uncertainties observed**.

Residues production in EU28 is estimated at 439 dry Mt/year, with four crops (wheat, maize, barley, rapeseed) accounting for 80% of this.

Some crops (e.g. sugar beet, rapeseed) **present an appreciable production trend** due to gradual changes in sown area, partially reflecting the effect of EU policies.

Thank you

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