BECOOL
Brazil-EU Cooperation for Development of Advanced Lignocellulosic Biofuels

Biomass production and feedstock diversification for advanced biofuels

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Project information

BECOOL

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Project website

Status

Ongoing project

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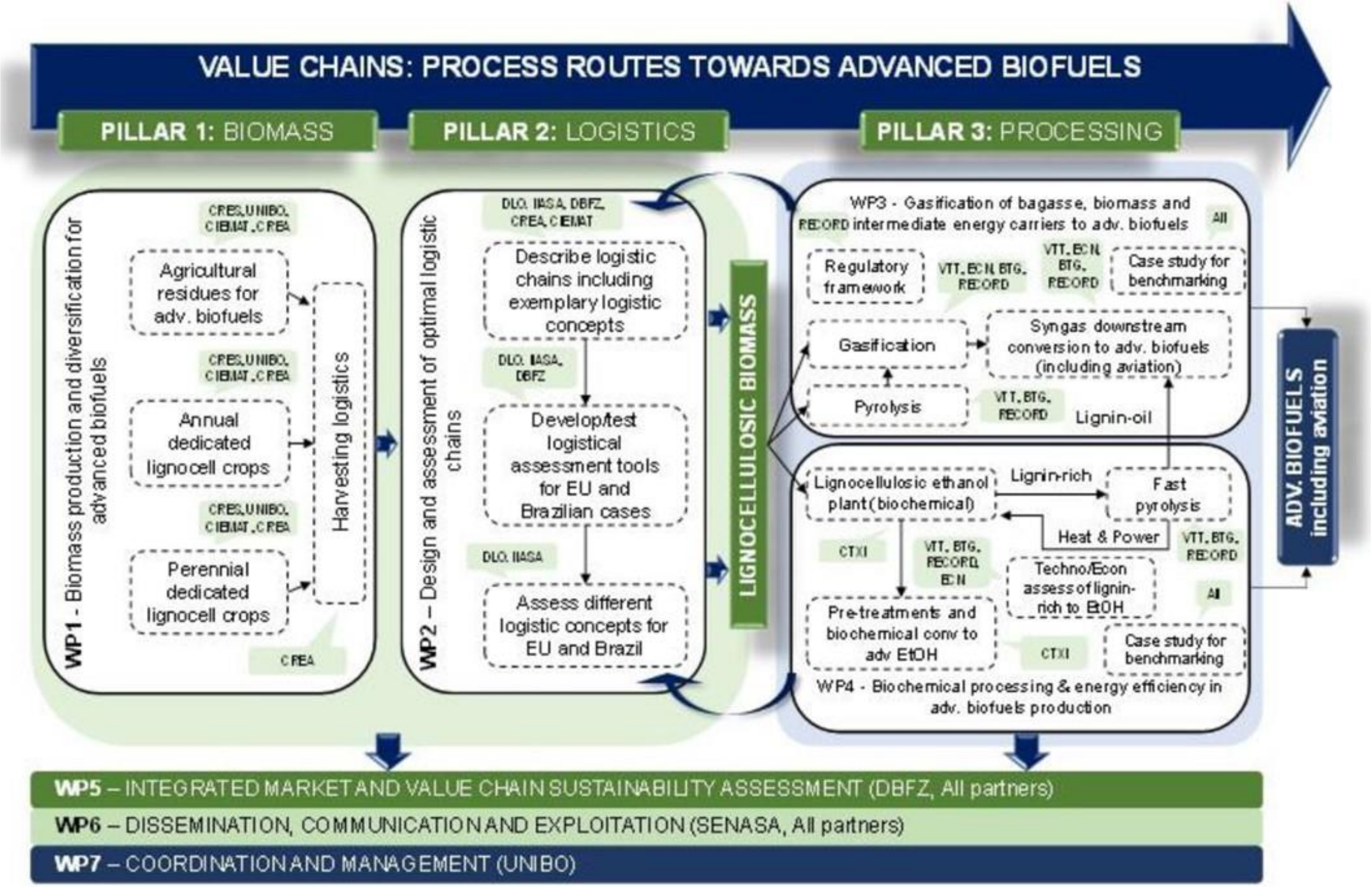
ALMA MATER STUDIORUM - UNIVERSITA DI BOLOGNA

Italy

BECOOL Consortium: 12 partners from 7 EU Countries (3 Universities, 2 large industries/SMEs, 7 Research Institutes)

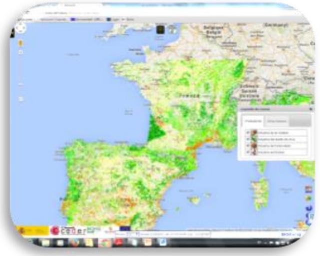
Flowchart

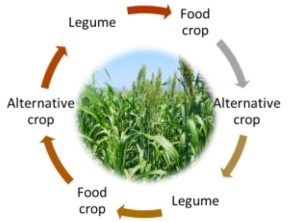

VALUE CHAINS: PROCESS ROUTES TOWARDS ADVANCED BIOFUELS
PILLAR 1: BIOMASS
PILLAR 2: LOGISTICS
PILLAR 3: PROCESSING
WP1 - Biomass production and diversification for advanced biofuels
CRES,UNIBO, CIEMAT,CREA
Agricultural residues for adv. biofuels
Annual dedicated lignocell crops
Perennial dedicated lignocell crops
Harvesting logistics
CREA
WP2 – Design and assessment of optimal logistic chains
DLO, IIASA, DBFZ, CREA, CIEMAT
Describe logistic chains including exemplary logistic concepts
DLO, IIASA, DBFZ
Develop/test logistical assessment tools for EU and Brazilian cases
DLO, IIASA
Assess different logistic concepts for EU and Brazil
LIGNOCELLULOSIC BIOMASS
WP3 - Gasification of bagasse, biomass and intermediate energy carriers to adv. biofuels
RECORD
All
Regulatory framework
VTT, ECN, BTG, RECORD
Case study for benchmarking
Gasification
Syngas downstream conversion to adv. biofuels (including aviation)
Pyrolysis
VTT, BTG, RECORD
Lignin-oil
Lignocellulosic ethanol plant (biochemical)
Lignin-rich
Fast pyrolysis
Heat & Power
CTXI
VTT, BTG, RECORD, ECN
Techno/Econ assess of lignin-rich to EtOH
Pre-treatments and biochemical conv to adv EtOH
Case study for benchmarking
WP4 - Biochemical processing & energy efficiency in adv. biofuels production
ADV. BIOFUELS including aviation
WP5 – INTEGRATED MARKET AND VALUE CHAIN SUSTAINABILITY ASSESSMENT (DBFZ, All partners)
WP6 – DISSEMINATION, COMMUNICATION AND EXPLOITATION (SENASA, All partners)
WP7 – COORDINATION AND MANAGEMENT (UNIBO)

Objectives

The objective of this work is **to increase lignocellulosic biomass production and feedstock diversification without reducing food crop land.**

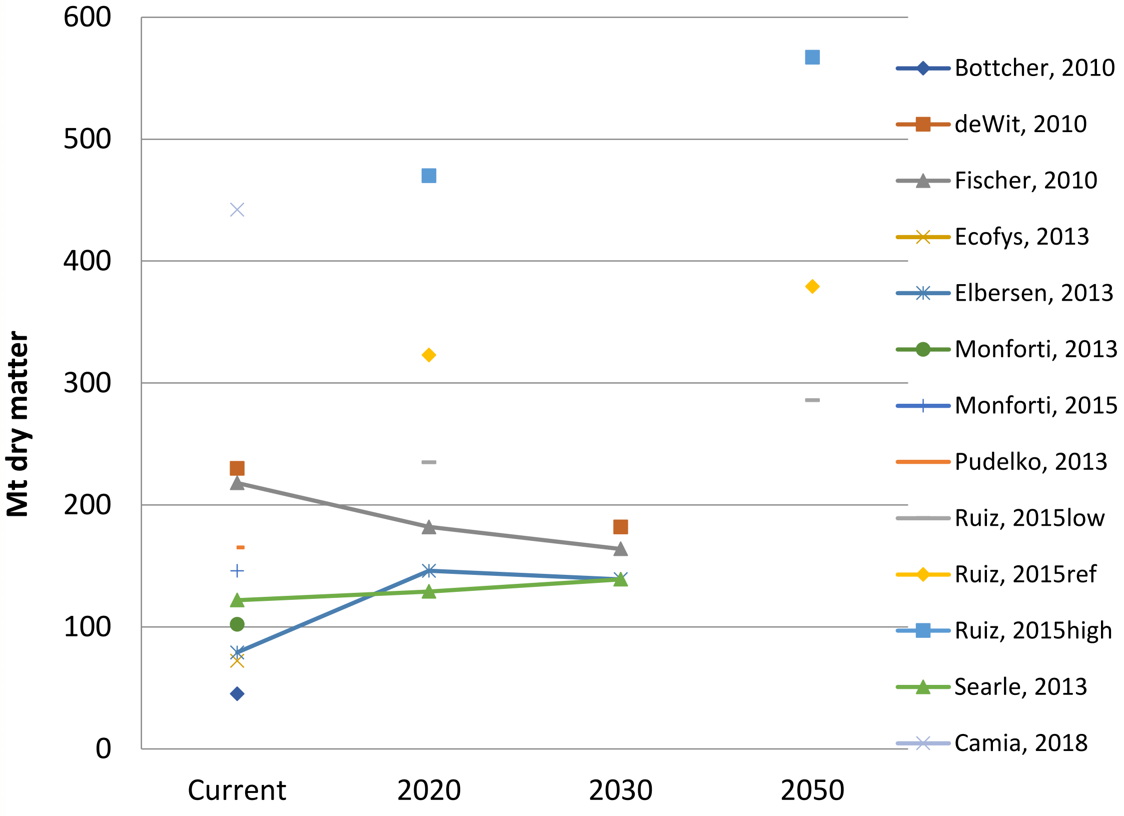
- **Review** of the available agricultural/forest/ industrial lignocellulosic residues of potential interest for advanced biofuels in EU and Brazil
- **Innovative crop rotations**, integrating annual dedicated lignocellulosic and food crops without reducing food crop land
- **Cultivation of perennial dedicated lignocellulosic crops** in marginal/idle lands





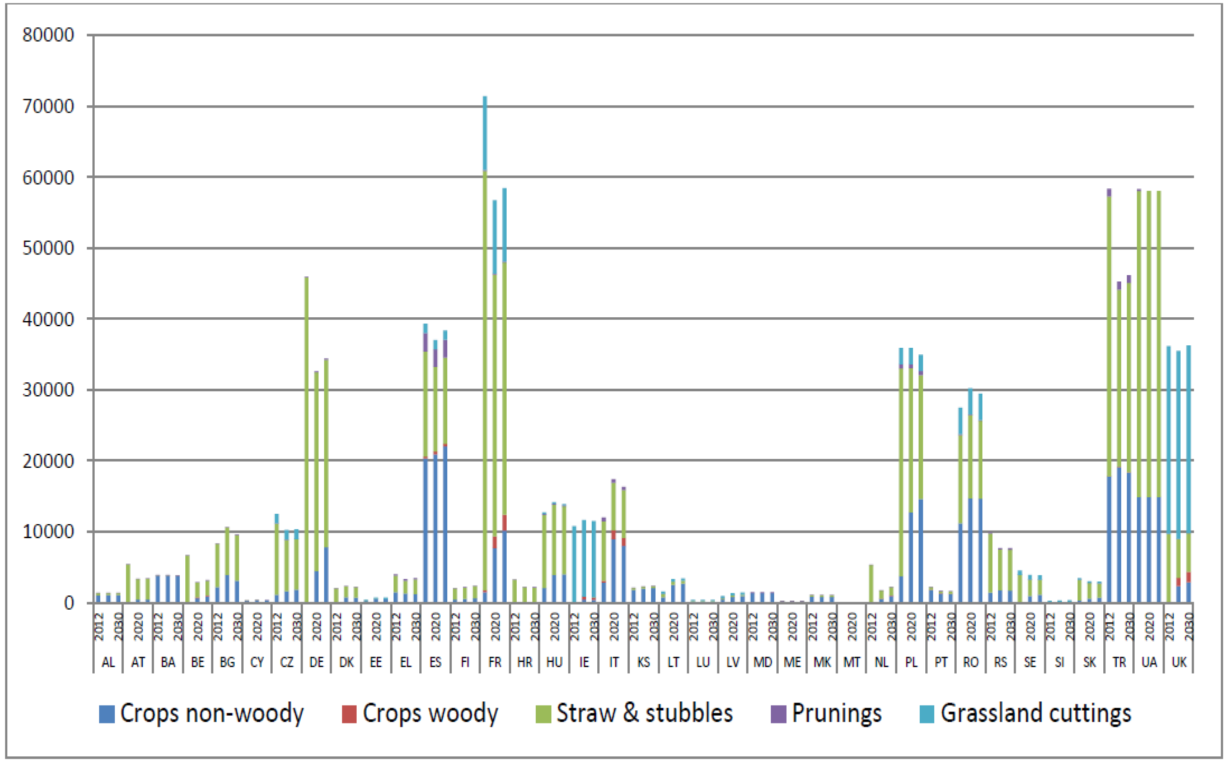
1. Review

Agricultural residues potential (mainly straw)



Source: Kluts et al., 2017, modified

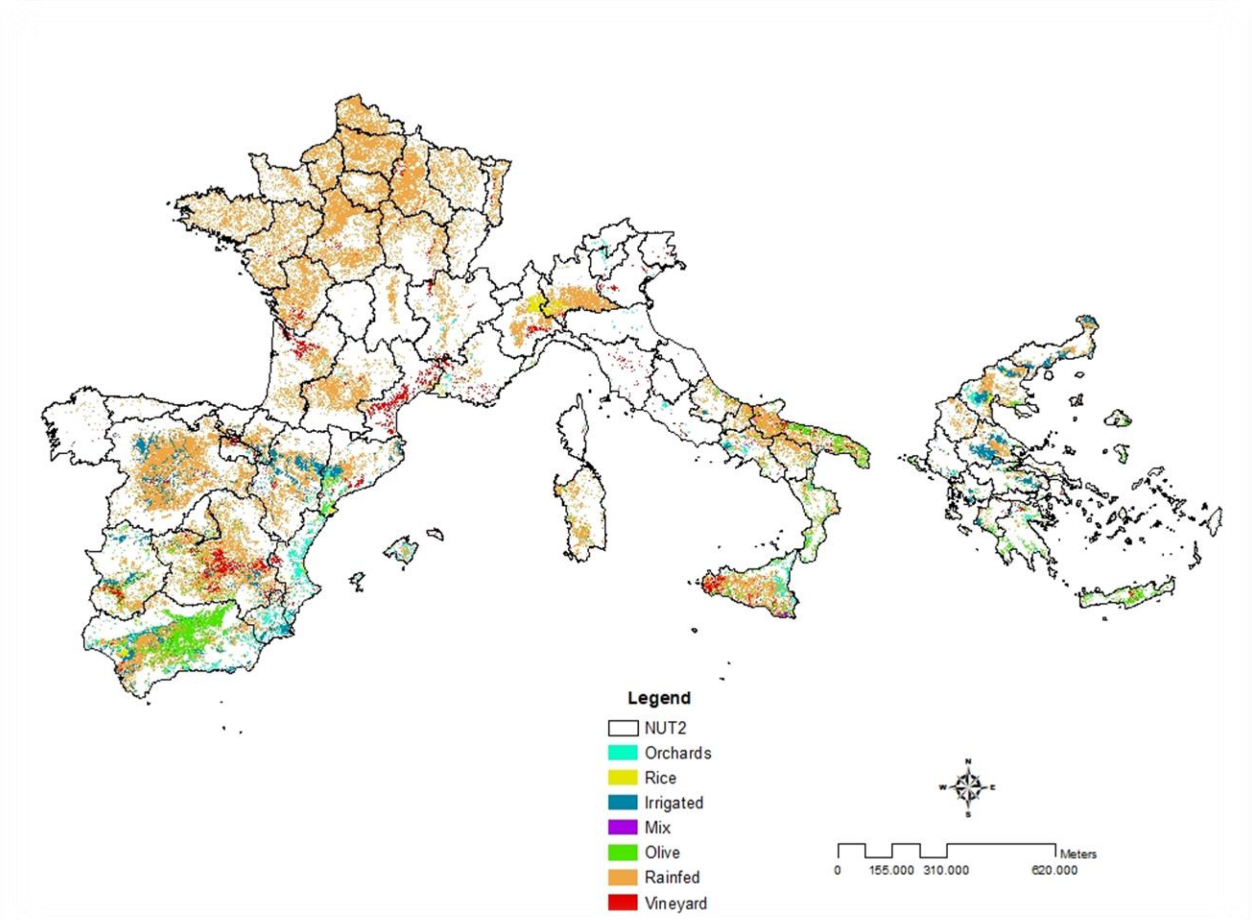
Total primary agricultural supply (kt dm) by country (2012, 2020, 2030)



Source: S2Biom project

- Straw is the dominating agricultural residue.
- Agricultural residues that are available and meet the sustainability criteria are reported to range from 139 to 182 in 2030 and could reach 286 to 567 MT dm in 2050.

Agricultural residues potential (mainly straw)

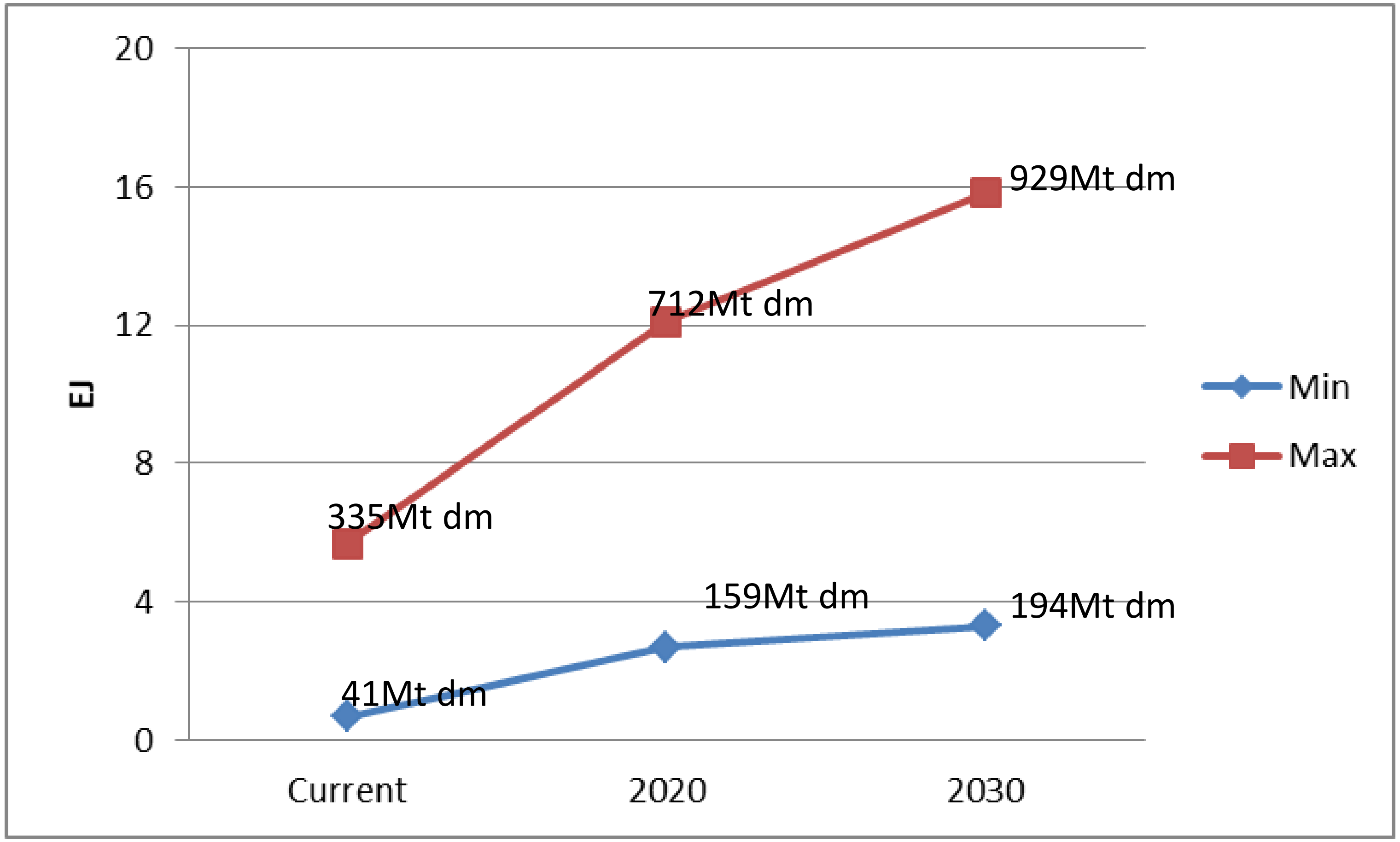


According to BIORAISE, in the four project countries, France, Greece, Italy and Spain, the total available residues account for 85.3 MT dm/y (87% agricultural).

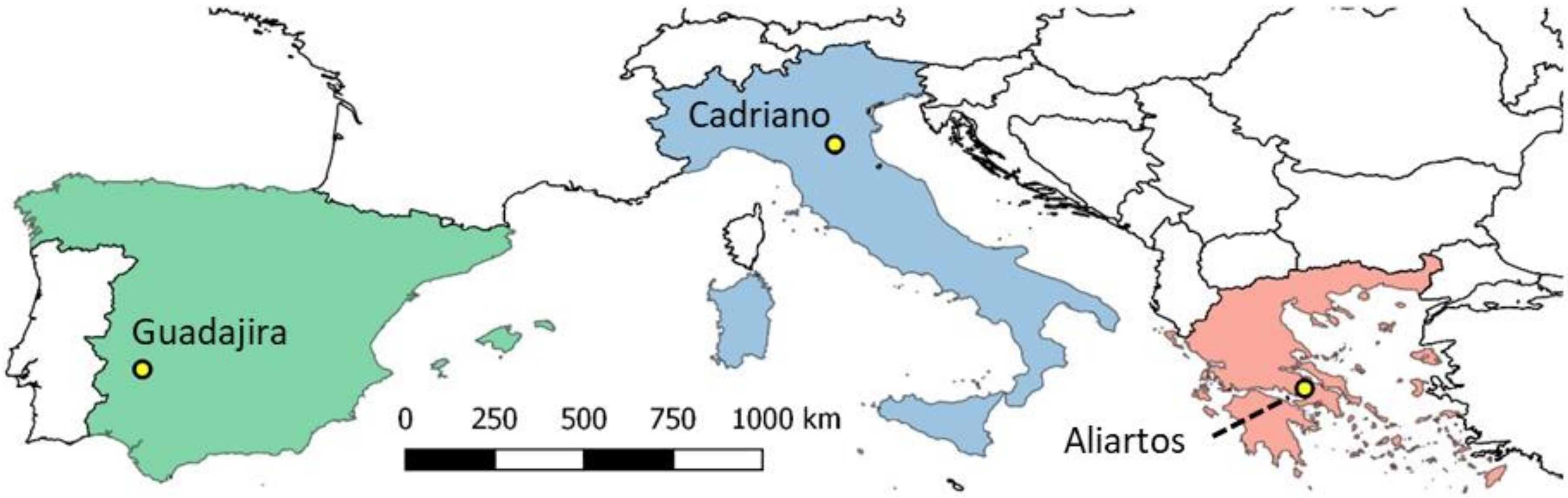
Straw from rainfed cereals is the dominating agricultural residue

Optimized logistics could significantly increase the exploitation of the residual biomass streams

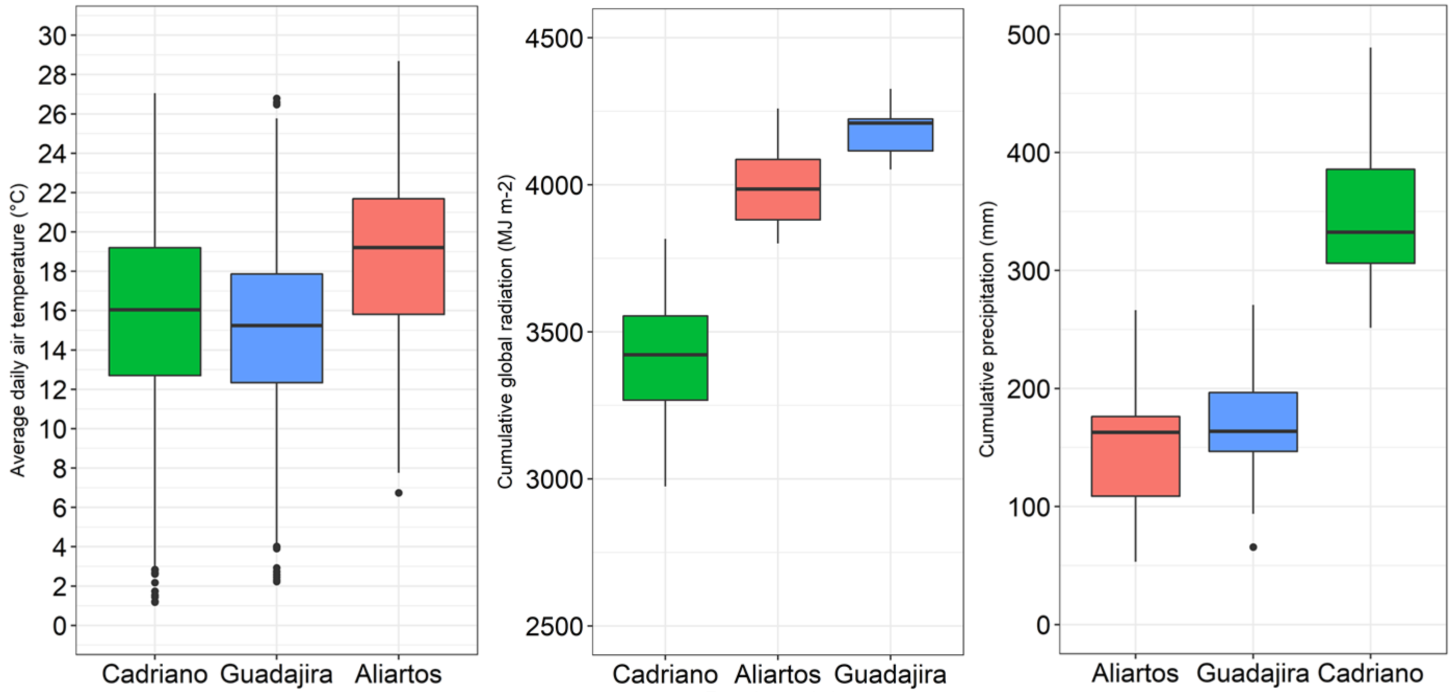
Range of technical potential for energy crops in Europe



Source: Kluts et al., 2017



Cadriano
Guadajira
Aliartos
0 250 500 750 1000 km

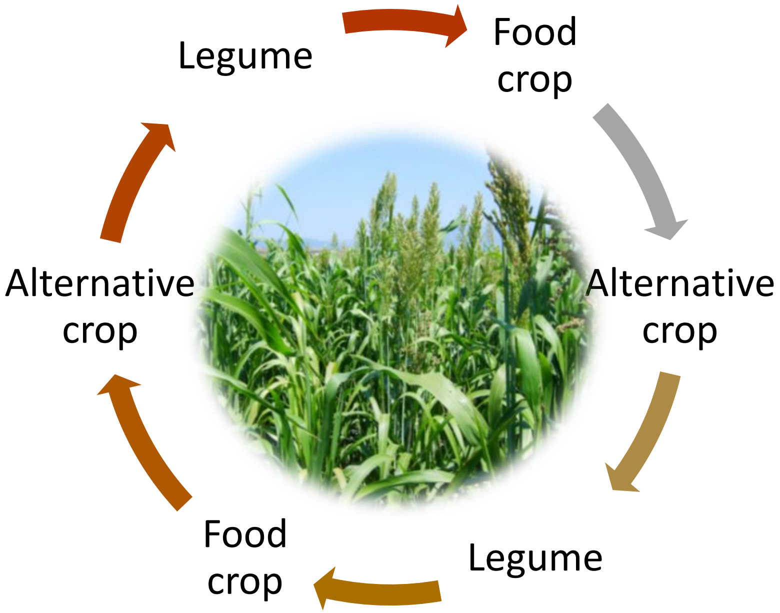


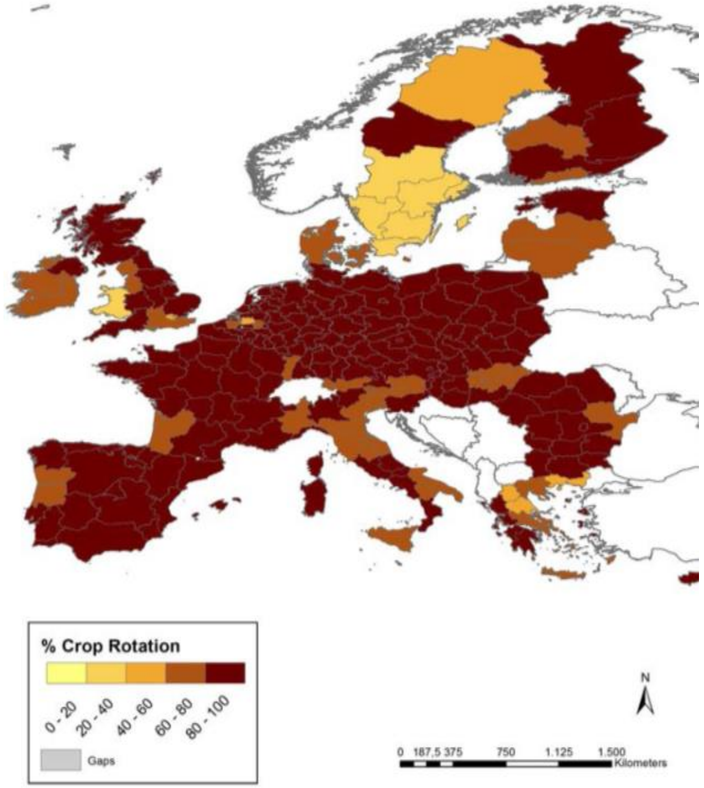
Average daily air temperature (°C)
Cadriano Guadajira Aliartos
Cumulative global radiation (MJ m-2)
Cadriano Aliartos Guadajira
Cumulative precipitation (mm)
Aliartos Guadajira Cadriano

Crop rotations

Objective:

To use innovative **crop rotation systems** in order to diversify crops, while increasing the annual quantity of lignocellulosic feedstock without reducing food crops land (i.e., higher land use ratio – LER).





Two thirds of the arable land in EU-28 is dominated by conventional crop rotations (mainly wheat-maize)

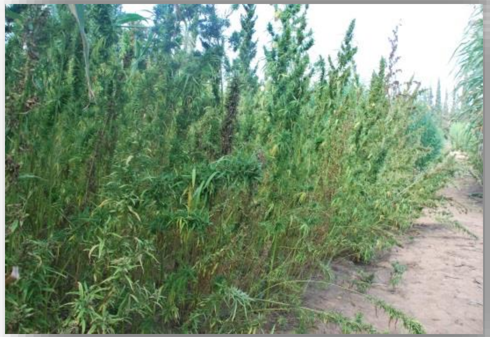
Advantages	Disadvantages
• Enhanced soil fertility and higher yields.	• Required higher levels of farm organization and farmer skills.
• Improved soil structure and maintenance of long-term productivity and organic matter	• Increased need of diversified agricultural equipment and agricultural supplies.
• Longer period of land cover with subsequent lower erosion.	• Reduced land availability for the most profitable crop.
• Reduced use of agricultural inputs such as agrochemicals and synthetic fertilizers.	• Unfamiliarity of farmers with several crop rotations', cultural and management requirements.
• Diversified production with greater market opportunities and lower economic and climatic risks.	• The fact of having to keep scheduled crop sequences leaves no choice to farmers to select crops contingently.
• Increased biodiversity and less monotony of the landscape.	
• Time-diluted farming activities.	

Source: Zegada-Lizarazu and Monti . Energy crops in rotation. A review. Biomass and bioenergy 35 (2011), 12-25.

Biomass or fiber sorghum (*Sorghum bicolor* L.), Poacea

Annual spring crop, originated from Asia, particularly suited to Mediterranean and Brazilian conditions as demonstrated in the SWEETFUEL project (www.sweetfuel-project.eu) in which a number of new biomass sorghum hybrids imported from Brazil were tested in South Europe and vice versa.

Many sorghum species, high photosynthetic efficiency, moderate water needs. Straw yields of 7-13 t/ha



Hemp (*Cannabis sativa*L.), Canabaceae

Annual spring short-day plant with good adaptability to several climate conditions.

Modest consumption of fertilizers or irrigation, with relative resistance to periodic water shortage, a good forecrop for cereals. It absorbs heavy metals such as Cd, Pb, Zn, Cu, for remediation of contaminated soils.

Straw yields: 8 t/ha (ginned straw: 6.45 t/ha), Seed yields: 0.8 t/ha, Fiber yields: 1.87 t/ha

Kenaf (*Hibiscus cannabinus* L.), Malvacea

Annual spring fiber crop, originated from tropical and subtropical Africa and Asia. According to flowering there are types of varieties: the early and the late-maturity varieties.

Sensitive to cool temperatures, highly productive in higher temperatures and moist soils.

Dry stem yields of 10-15 t/ha have been recorded in experimental fields in south EU.

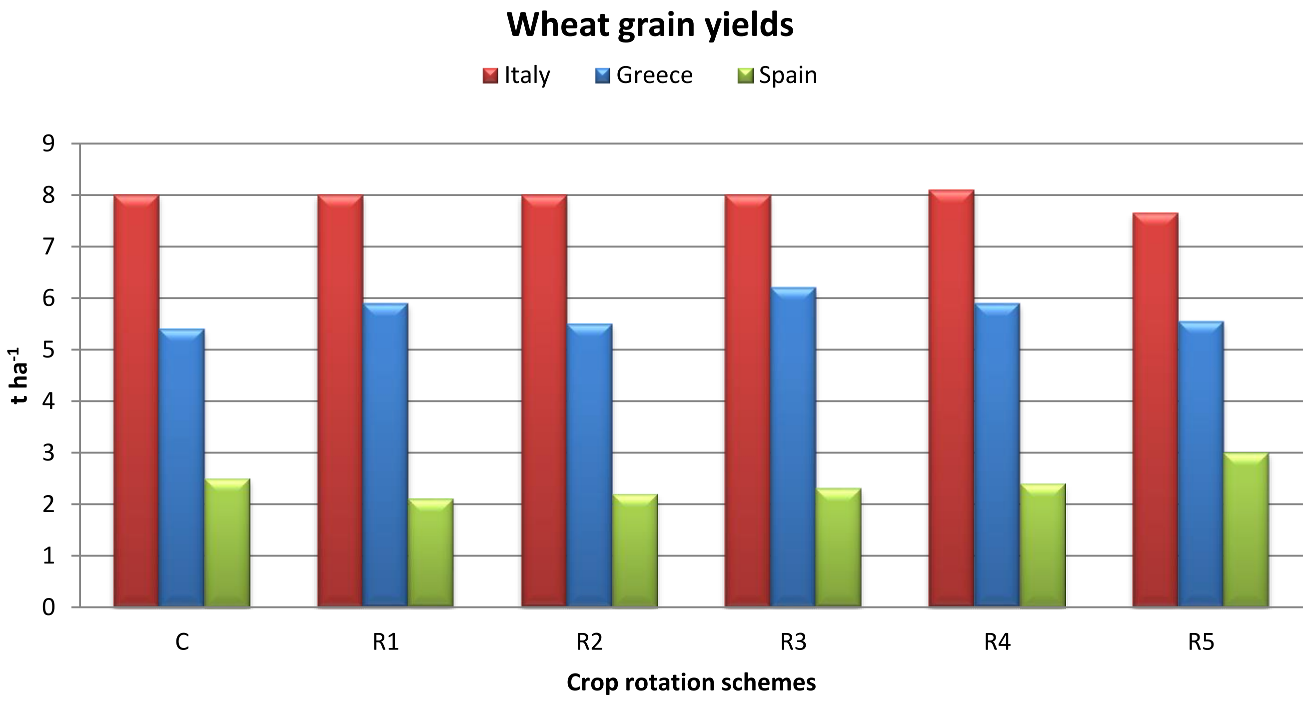
Sunn Hemp (*Crotalaria juncea* L.), Fabacea

A tropical Asian plant, generally considered to have originated in India. Now widely grown throughout the tropics and subtropics as a source of green manure, fodder and lignified fiber obtained from its stem.

Through biological N2 fixation, it can improve soil fertility and the yields of succeeding food crops reducing also inputs requirement. Can be an invasive weed and has been listed as a noxious weed in some jurisdictions

Grain and biomass yields along three year rotation

	2017	2018	2019	2020	2021	202
	A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M
C	Maize	Wheat		Maize	Wheat	
R1	Maize	Sunn Hemp, Wheat	Sunn Hemp	Maize	Sunn Hemp, Wheat	
R2	Maize	Fiber sorghum, Wheat	Sunn Hemp	Maize	Fiber sorghum, Wheat	
R3	Maize	Kenaf, Wheat	Sunn Hemp	Maize	Kenaf, Wheat	
R4	Maize	Hemp, Wheat	Sunn Hemp	Maize	Hemp, Wheat	
R5	Sunn Hemp, Wheat	Sunn Hemp, Wheat	Sunn Hemp, Wheat	Sunn Hemp, Wheat	Sunn Hemp, Wheat	

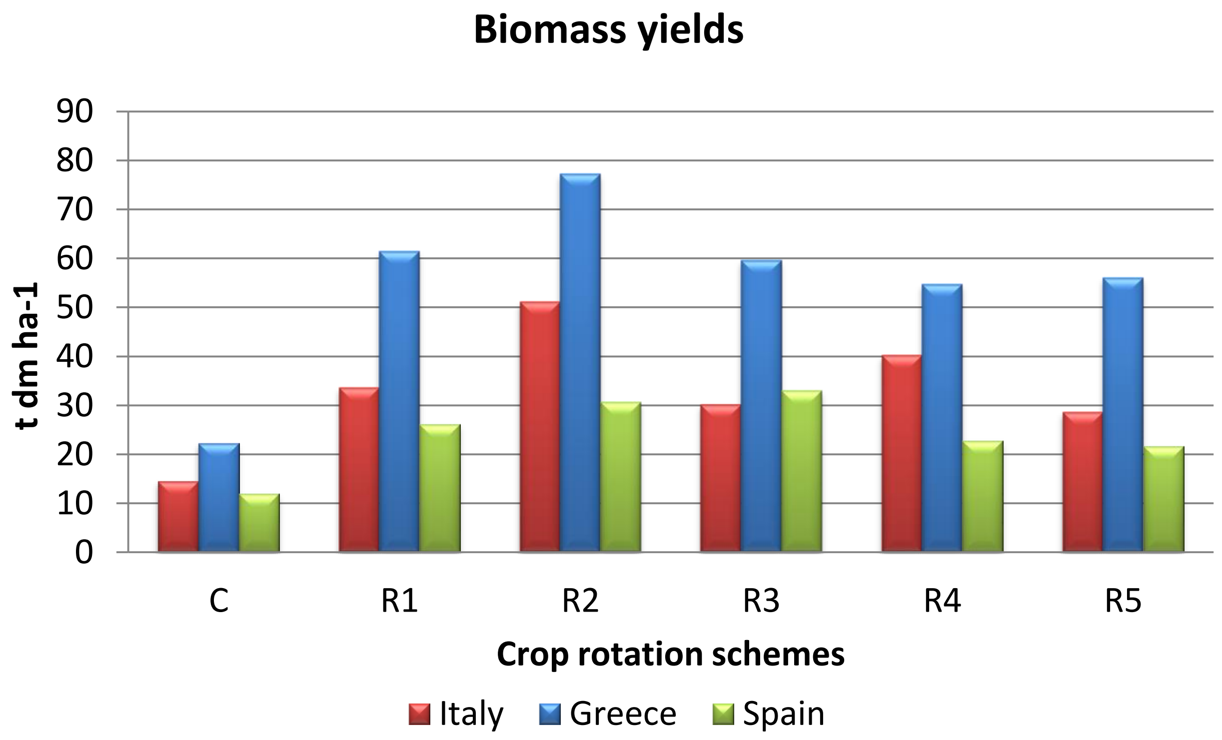


➢ **Wheat grain yields** were not affected by the precedent crops in all rotations and environments

Grain and biomass yields along three year rotation

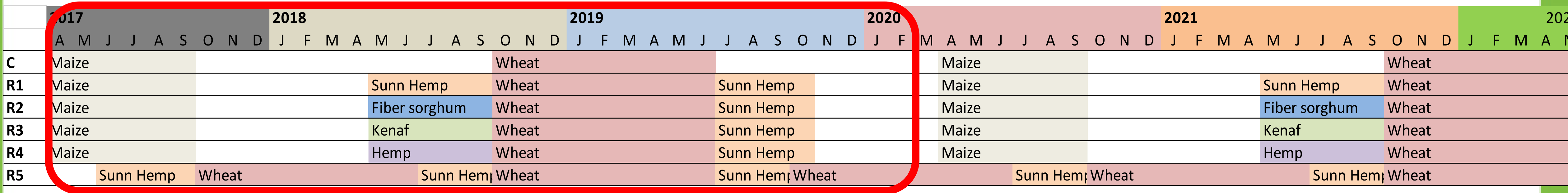
2017 | 2018 | 2019 | 2020 | 2021 | 202…

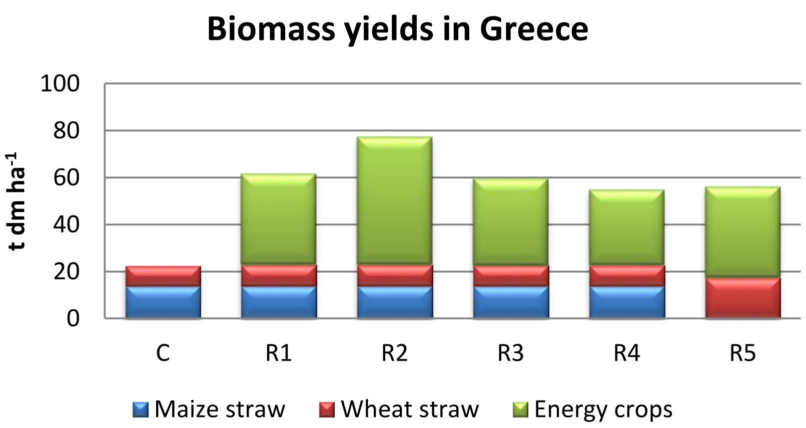
C	Maize					Wheat			Maize					Wheat
R1	Maize			Sunn Hemp		Wheat	Sunn Hemp		Maize			Sunn Hemp		Wheat
R2	Maize			Fiber sorghum		Wheat	Sunn Hemp		Maize			Fiber sorghum		Wheat
R3	Maize			Kenaf		Wheat	Sunn Hemp		Maize			Kenaf		Wheat
R4	Maize			Hemp		Wheat	Sunn Hemp		Maize			Hemp		Wheat
R5		Sunn Hemp	Wheat		Sunn Hemp	Wheat	Sunn Hemp	Wheat		Sunn Hemp	Wheat		Sunn Hemp	Wheat

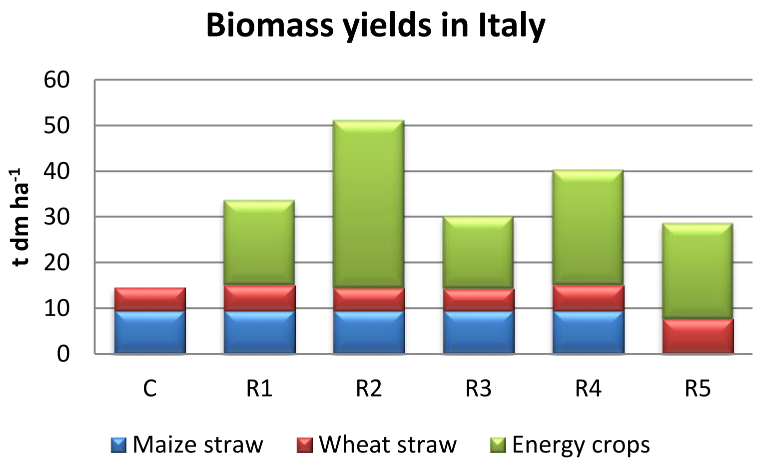


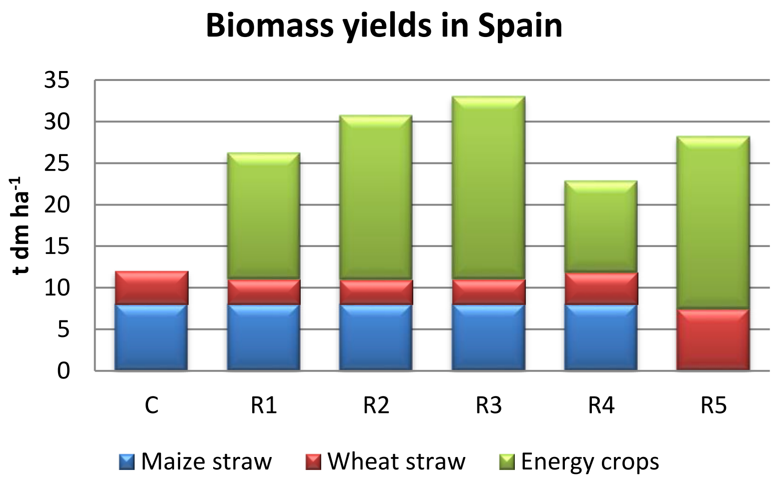
- In contrast to wheat grain yields, biomass yields increased when the energy/ industrial crops were included in the rotation scheme.
- The rotation **maize-fiber sorghum-wheat-sunn hemp (R2)** lead to the highest biomass yields in Italy and Greece, whereas in Spain the most productive one was the rotation **maize-kenaf-wheat-sunn hemp (R3)**.
- The lowest biomass yields were recorded in the **conventional maize –fallow –wheat rotation** (C), in all environments.

Grain and biomass yields along three year rotation









Why perennials?

- Can grow on marginal land facing bio-physical constraints, underutilized land including land where either food or feed production is economically non feasible, thus to not compete against food crops and further diversify farm productivity.
- Low input requirements, making maintenance costs low, over 10-25 years of productive life coupled with considerable yielding potential.
- Offer not only an important energy resource but can also positively contribute to biodiversity, soil protection, landscape improvement etc.

Giant reed (*Arundo donax* L.), Poacea

Perennial rhizomatous grass, native in Mediterranean Basin.

Low input crop, able to grow in arid lands, mechanized production (planting/harvesting equipment)

Highly productive and fast-growing crop in temperate climates with yields of 20-30 t/ha (d.b.)

Relatively high biomass production costs due to rhizome establishment

Miscanthus giganteus (Miscanthus x giganteus), Poacea

Perennial rhizomatous grass with good adaptability to several climate conditions.

Low input crop, highly productive and fast-growing crop throughout Europe. Fully mechanized production. Relatively high biomass production costs due to rhizome establishment.

Yields of 20-30 t/ha can be achieved

Switchgrass (*Panicum virgatum* L.), Poacea

Perennial rhizomatous grass; high genetic variability (upland varieties for N. Europe and lowland for South.

Low crop inputs and biomass production costs. High nutrient and water use efficiency. Established by seeds. Fully mechanized production and long harvest window expanded from late autumn to early spring; Low moisture content at late harvest. Yields vary from 8 to 25 t/ha (d.b)

Tall wheat grass (*Thinopyrum ponticum,* Podp.), Poacea

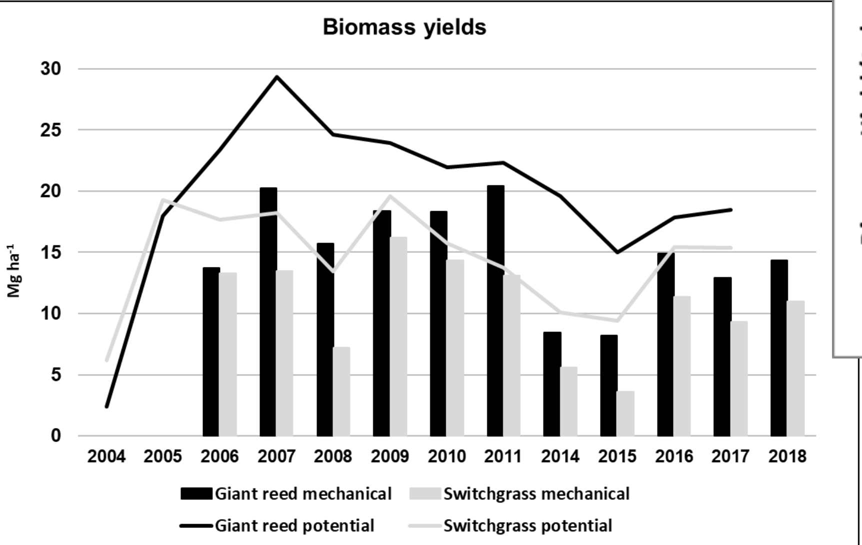
Perennial grass, originally from Turkey, Asia Minor and Russia.

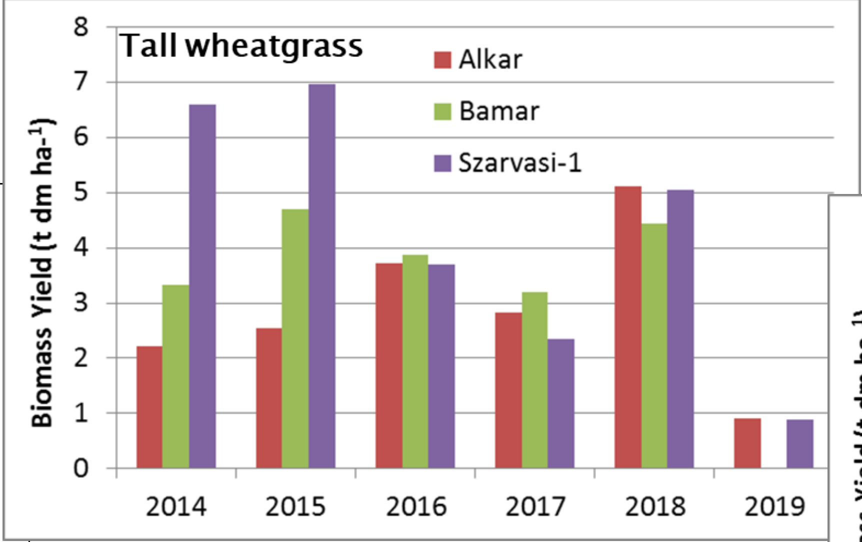
Cool-season perennial bunchgrass with a fibrous root system, typically grown as forage crop and for hay.

Low input crop, one of the most saline or alkali tolerant cultivated grasses that can help reduce soil salinity. Fully mechanized production.

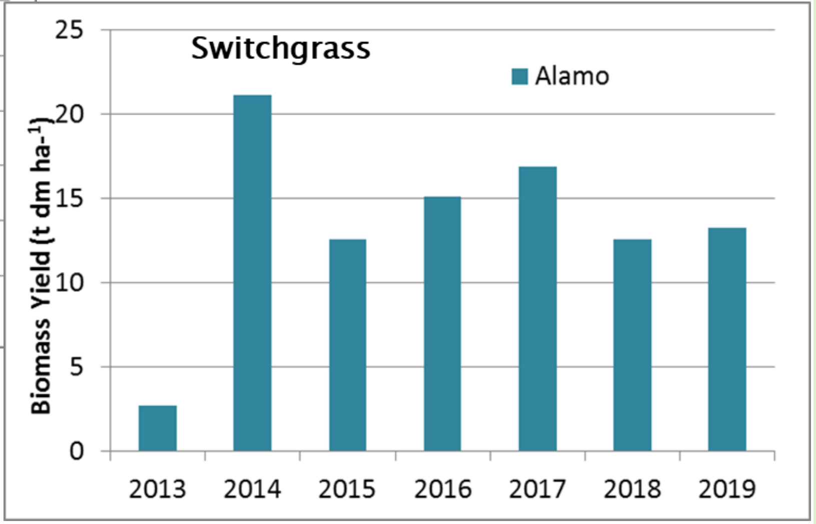
3. Perennial grasses

In Italy

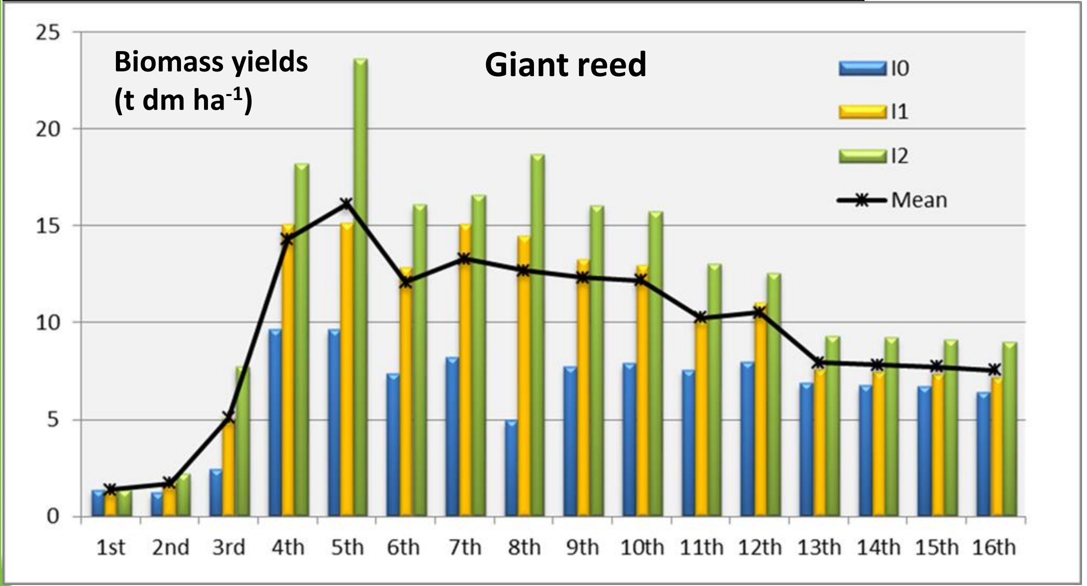


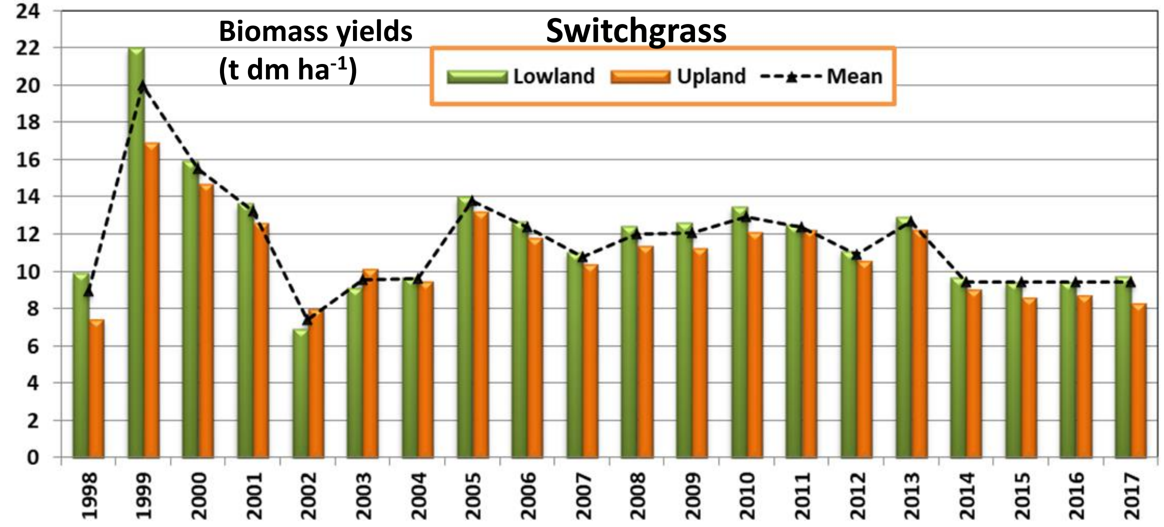


In Spain



In Greece





Conclusions

Biomass resource estimations are diverse and sometimes contradictory because final targets, models and assumptions are diversified.

In all studies, straw is the dominating agricultural residue. Optimized logistics could significantly increase the energy exploitation of the residual biomass types.

Energy crops can be a significant asset to increase biomass feedstock that would be able to cover high biomass needs. However, stricter sustainability constraints on biodiversity conservation and GHG emissions will hinder their development.

All studies show a shift in shares from annual to perennial energy crops, due to the applied sustainability constraints; the stricter they are, the higher share of perennials will be.

Annual crop rotations did not affect the grain yields but did increase significantly the biomass yields

Perennial crops showed a range of biomass yields from as low as 8 t ha^{-1} (d.b) to 15 t ha^{-1} (d.b), or sometimes higher, depending on the climate, soil quality (fertile, arid lands) and cultivation conditions (rainfed, nitrogen applications) and years of plantations.

Thank you for your attention!

Partners

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