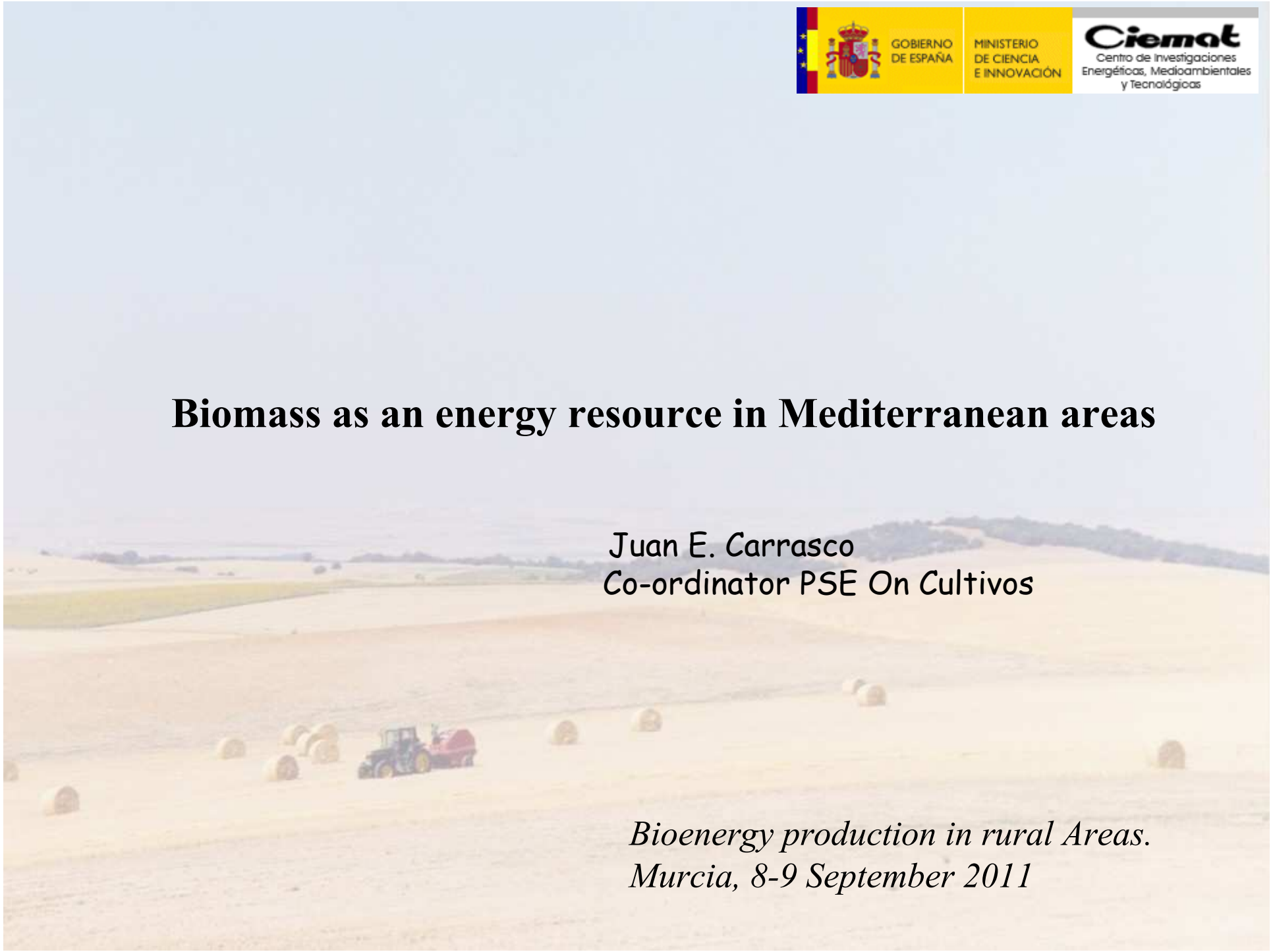

Biomass as an energy resource in Mediterranean areas

Juan E. Carrasco
Co-ordinator PSE On Cultivos

Bioenergy production in rural Areas.
Murcia, 8-9 September 2011

Some considerations and facts on biomass production and use in the mediterranean area

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✓ The sustainable forest biomass production is much lower and disperse (typically 0,7-1,5t DM/ha.year) than in northern EU countries (> 2 tDM/ha.year), which, in combination with complicated orographic conditions in many of the forest areas cause a very high biomass collection costs (50-60€tDM in plain forest areas in Spain).

The forest biomass energy use is more viable for thermal applications and as an accompanying fuel for power plants, but its availability is somehow limited unless very important supporting measures are stablished. The use can mainly be encouraged by the necessity to clean the forest to prevent fires risk.

Some considerations and facts on biomass production and use in the mediterranean area

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✓ Due to climatic conditions the annual production (t/ha) of most important agricultural residues like straw is lower than in the central EU countries and present large annual variations which strongly affects the availability of this type of biomass for energy use.

✓ A significant ammounts of woody residues (about 10 Mt DM/year on average in Spain) are produced from typical mediterranean crops like olive tree and grapeyard prunnings. Considerable effort is being made in some countries like Spain for mechanization of the collection of these residues, a part of which are traditionally used as energy source, mainly in domestic and tertiary sectors.

The availability of the potential of agricultural residues for energy use in the mediterranean region is very limited due to the low biomass quality and the large annual variations of the production and price (straw) and the high collection costs.

Needs for development of energy crops in the mediterranean region.

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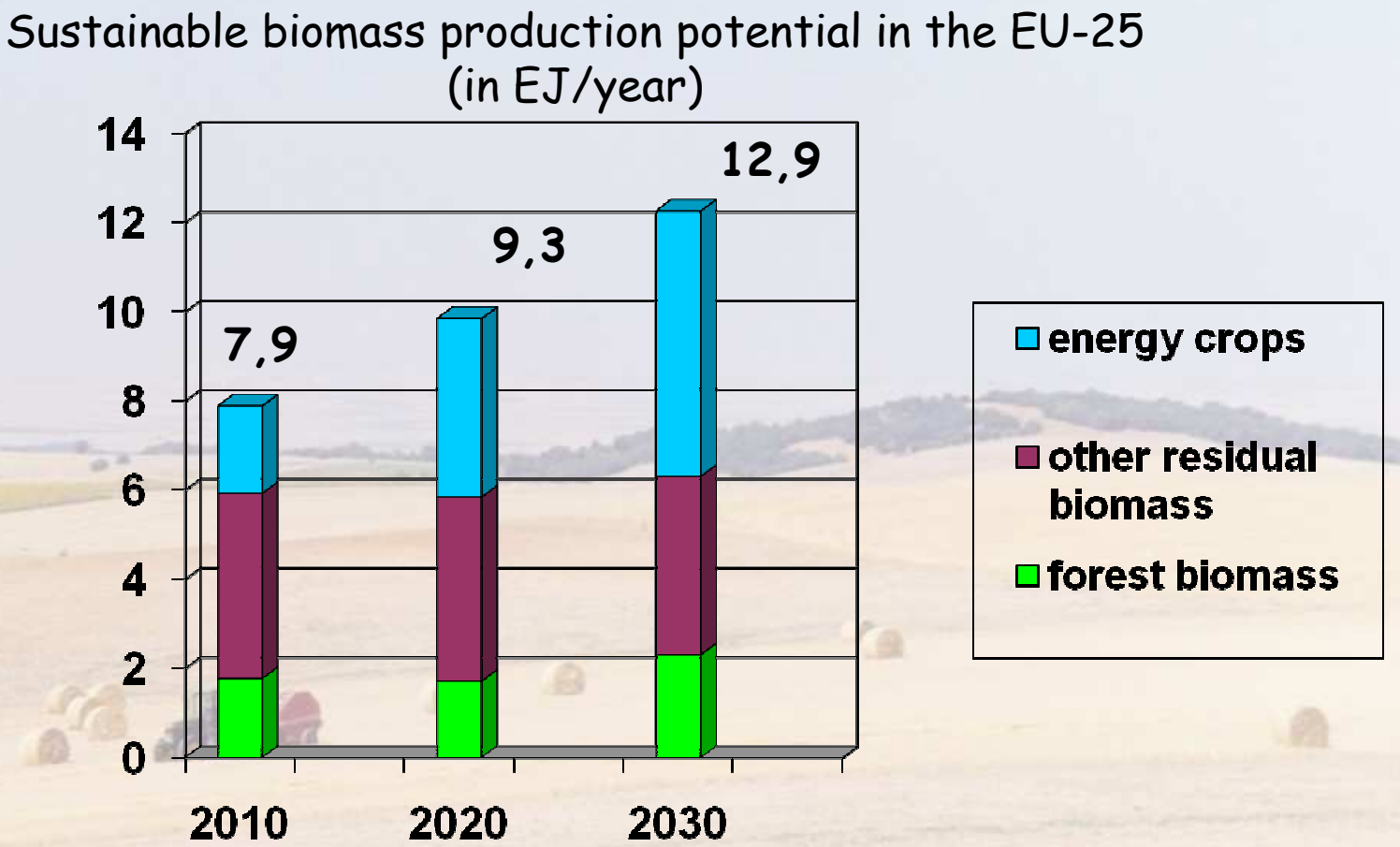
• Need of implementing alternatives in agricultural and forest land due in view of the low sustainability of traditional agriculture and forest practises as a consecuence of the small production and profitability of most of forest areas, and the variable agricultural crop yields in dry conditions and the progressive higher costs and reduced water availability in many irrigation areas.

•Need to have available aditional source of biomass due to limited potential and the large annual variations of agricultural residual biomass production which negatively affects its availability for energy purposes.

•Need to reduce the environmental impact of the intensive agriculture, as well as the risk of erosion and deseretification of the abandoned lands.

The energy crops are the only biomass source with a sustainable growing production potential in the EU and in the mediterranean region



Source EEA, 2006

In Spain, in October 2005, a consortium integrated by 24 enterprises, farmers and other organisations,and 8 universities and R&D organisms start a Singular and Strategic national project for demonstration and development of energy production from energy crops biomass (PSE On Cultivos)

OBJECTIVES

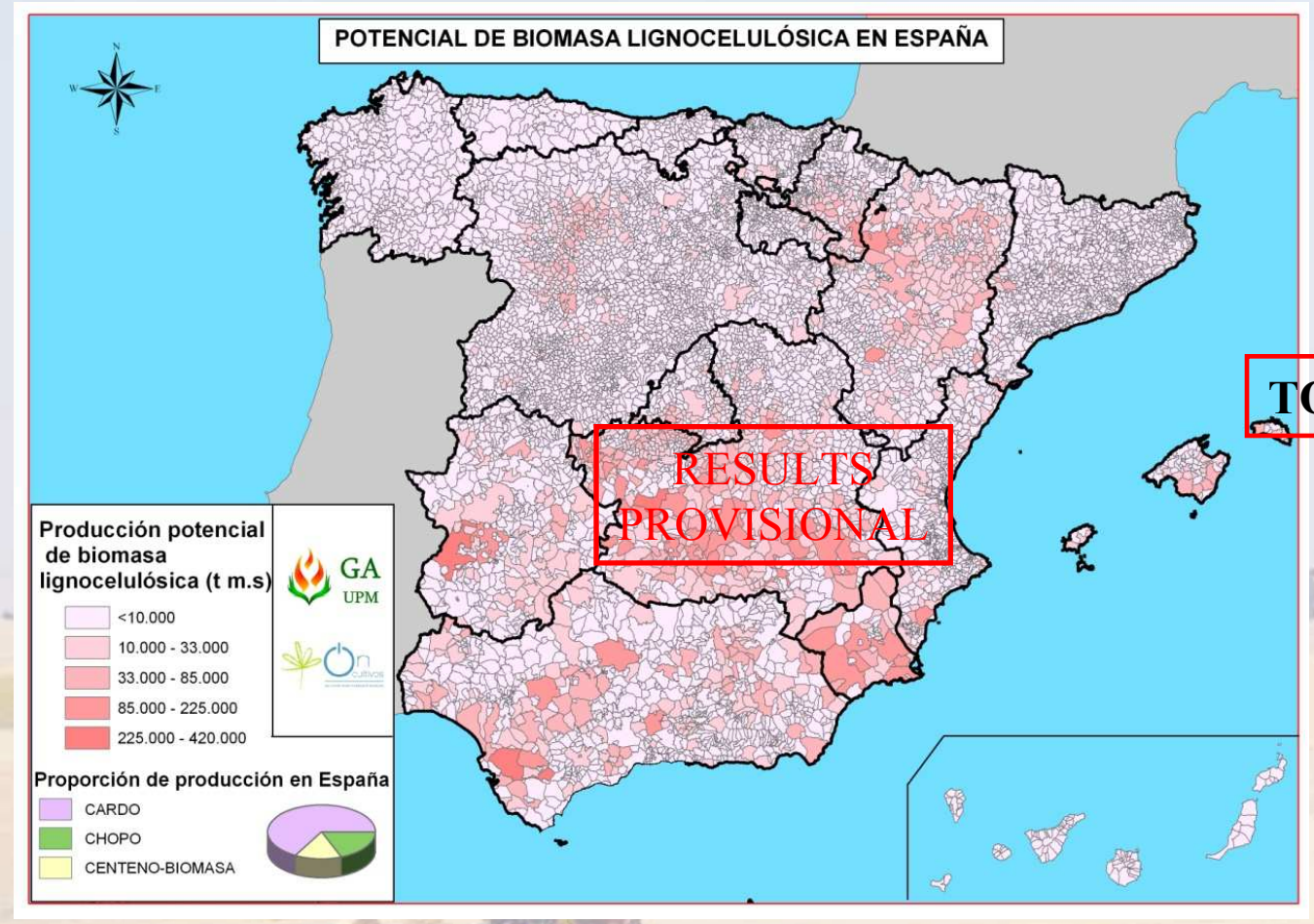
✓To demonstrate the energy chains of the energy crops with more potential in Spain and considering the more important energy applications.

✓ To evaluate the sustainable potential of energy crops in Spain determining the most relevant energy crops, the biomass production and costs, as well as different environmental indicators in relation to their introduction al local level,Llevar a cabo un desarrollo tecnológico tanto a nivel de la producción de biomasa, como de las tecnologías de conversión energética

✓ To carry out a technological development of energy crops production and of the conversion technologies.

DENERAL DATA OF On Cultivos PROJECT

Duration	**2005-2012**
Bdget (M€)	**aprox 62M€**
Energy crops area implemnted	**About 3000 ha**
Regions involved in crops demonstration programme (2011)	**Andalucía, Aragón, Castilla la Mancha, Castilla y León, Cataluña, Extremadura, Madrid, Navarra and Valencia (associated region)**

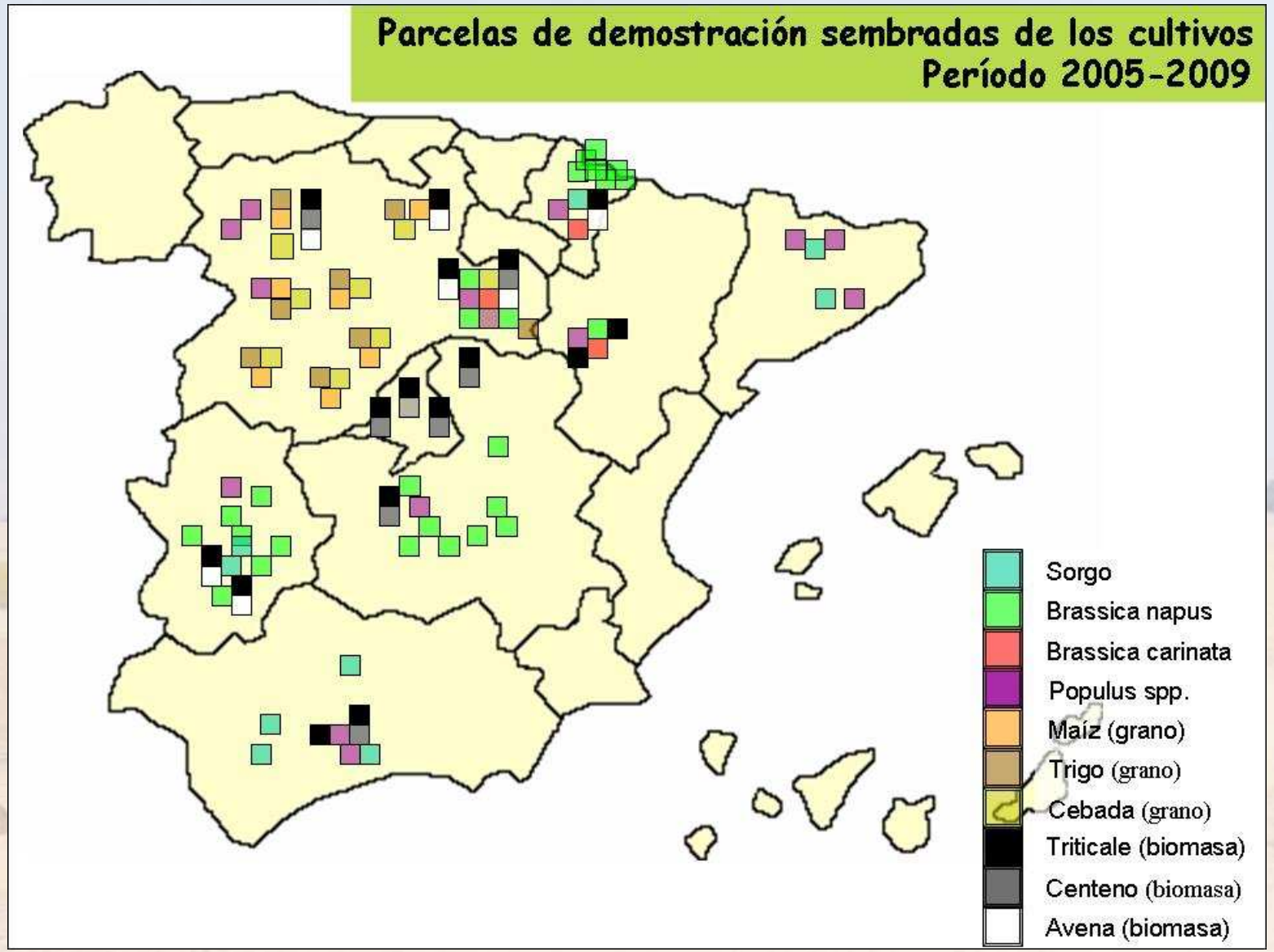


TOTAL: 8,3 MToe/year

Minimum estimated potential for lignocellulosic energy crops under present conditions in Spain based crdoon, poplar and rye biomass

Source: GA-UPM

Demonstrative parcels in On Cultivos. Period 2005-2009



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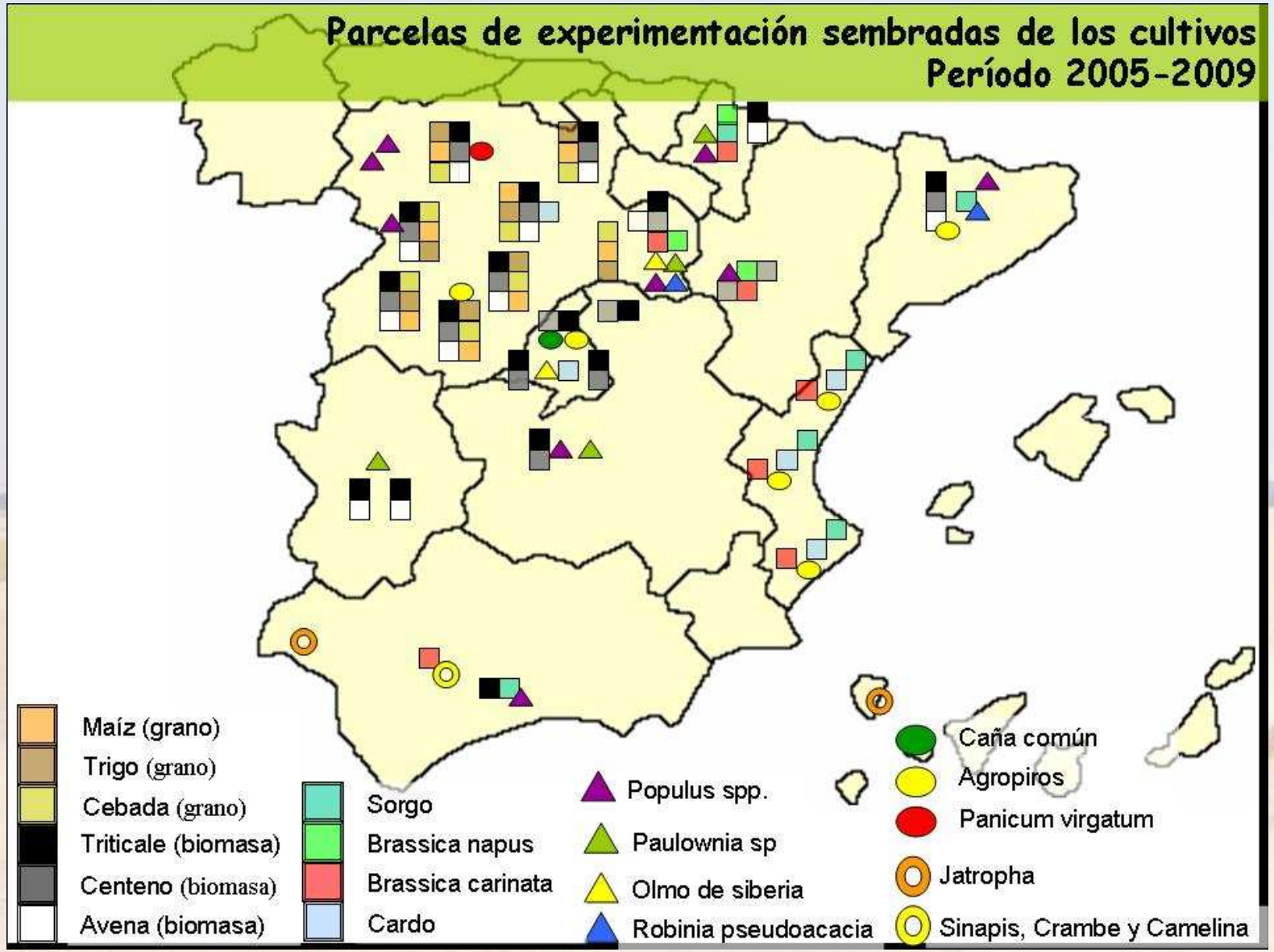
Experiemental parcels in On Cultivos. Period 2005-2009



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Preliminary evaluation results with cereals (wheat, barley, maize) for bioethanol production in On Cultivos

The production potential of bioethanol with national raw materials in Spain is very small from the economic and environmental (GHG savings compared to fossil transport fuels) points of view, even when very high yielding varieties (more than 15 and 12 t/ha grain for maize and wheat, respectively) are considered.

Preliminary evaluation of rapeseed for biodiesel production in On Cultivos

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- The rapeseed is a very technical crops that present important implantation problems in dry conditions in Spain given the tipical pluviometry in most of the spanish areas.

-Under irrigation conditions and in the most humid areas, give seed yields about 3500-4500kg/ha, which in some cases could make this crop attractive for biodiesel production when introduced in rotation with cereals but, in general, the costs are not competitive with foreign rapeseed due to the lower yield in most typical dry conditions growth and the high land and irrigation water costs in the most productive areas (Castilla La Mancha, Andalucía).

Parcela de demostración de colza.
Proyecto On Cultivos.
Soria, Mayo de 2007
Foto: Fundación Soriactiva

Main needs for crop development:

- Selection and acclimatation of vareties to spanish edaphoclimatic conditions in order to improve the seeds nascence.

Preliminary evaluation results of short rotation poplar in On Cultivos

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•The development of the different clones in Spain is very influenced by the local edaphoclimatic conditions. Up to know AF2, y Monviso arehighlighting clones in most of the testing areas. The clon I-214 offers internediate results in all cases.

•The expected biomass production from this crop in Spain are 15-25 tDM/ha. which is corroborated by the first biomass productive collection in Almazán (36-60tDM/ha after three years plantation), and the estimatives in the established parcels.
•The studies on course in regard to crop water requierements reveal important differences between clones. AF2 and Monviso clones are very efficient in the water use. According the first estimatives, the poplar water requirements could be 2500-3500 m3/ha, under spanish conditions

Poplar demonstrative parcel in Valtierra . ACCIONA (Junio 2009, NAVARRA).

Photo: CIEMAT

Main needs for crop development:

•Improvements in the mechanizationMecanización de la recolección (more flexible machines)
• Identification of the clones more adapted to local conditions
•Determination of water requirements
•Determination of more adequate tree densities and rotation cycles.

Preliminary evaluation of Paulownia in On Cultivos

Very high implantation costs (about 1,5-2€/plant) although the optimal density of the energy plantations is not established

Needs of irrigation during the first-second year after planting

Very sensitive to frozen and soil floods.

According to preliminary results of the IFAPA-SAVB testing programme in Andalucía, the paulownia biomass production is lower than of eucaliptus and poplar in that region.

Preliminary evaluation results ofSorghum for biomass in On Cultivos

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Annual Biomass yields :

Navarra (Average: 13 t/ha, Maximum 16 t/ha; 2006-2008). No representative conditions.

Andalucia (Average: 22 t/ha, Maximum 60t/ha; 2006-2007)

Cataluña (15-20 t/ha, 2008-2009)

Experimental parcel of biomass sorghum ITGA (NAVARRA). 2008.

Main needs for development:

-Selection of more suitable genetic material (lines, hibrids)

- Development of biomass logistics (collection, storage).

-Determination of fertilizers and water requirements

Test of sorghum harvesting and baling developed by the enterprise Abencis in Navarra (September 2009)

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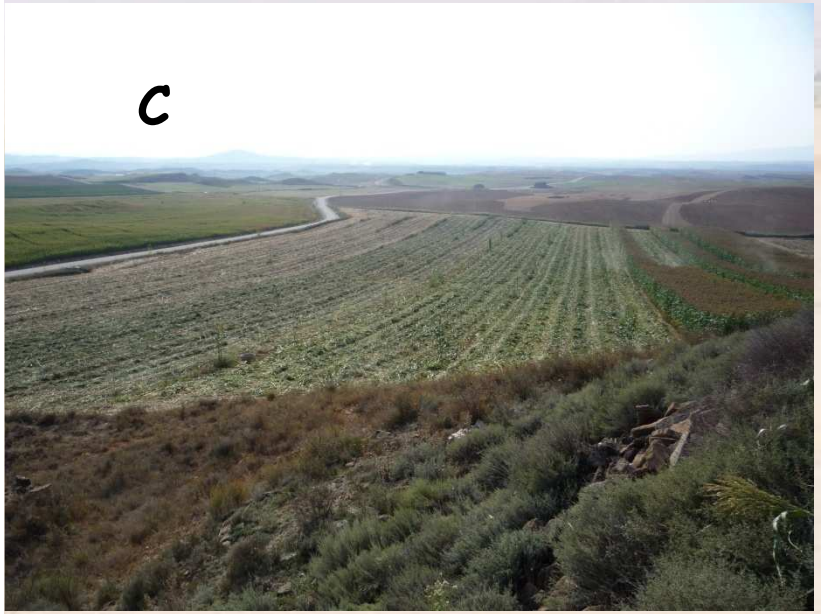
A

B

C



A y B.- Machinery for sorghum collection and biomass baling.

C.- On field drying of conditioned soghum biomass previous to baling (see gradient of colour on the parcel).

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Double cropping systems based on winter biomass cereal and sor.ghum can be an alternative to optimise the biomass production optimising the water use

Preliminary Evaluation results of double cropping sstems with sorghum-cereal in On Cultivos

	LEON (Northern Spain)		GRANADA (Southern Spain)	
Data and resources	*Triticale*	*Sorghum*	*Triticale*	*Sorghum*
Costs (€/ha)	**668**	**607**	**609**	**729**
Land preparation	90	0	80	0
Seeds	114	140	163	140
Sowing	30	40	35	40
Irrigation	0	90	0	170
Fertilizers	170	64,8	52,8	0
Pesticides	51	0	0	0
Spreading operations	44	10	7	10
Harvest operations	163	259	268	364,6
Monitoring	5	3	3	4
Credit rate	0	0	0	0
Income (€/ha)	595	765	1148	1318
Rental land cost	255	125	445	335
Gross margins (€/ha)	-327	33	94	254
Total annual gross margin (€/ha)		**-295**		**348**
Breakeven point (odt/ha.year)		**19**		**23**
Biomass productionCost (€/odt)		79,660875		46,11724138

Preliminary evaluation results of sorghum for electricity production in Spain

-The biomass sorghum has a potential interest to secure the biomass supply of power plants.

-It has not been possible to express the potential of this crop in the tested areas (about 30tDM/ha.year in Andalucía and Extremadura) partly because the lack of knowledgement about growth conditions as weel as the difficulties for biomass collection at the end of the autumm, when rainfalls occur.

-The lines (e.g. H133) use to show a bigger vigour and production than the hybrid varieties, but the collection with the existing machinery is more difficult due to the thicker stems.

- The energy yield for electricity production has been evaluated of about 1,3-1,5 for biomass yields of 18-20tDM/ha which is not a satisfactory value to use this crop for energy. Increased yields and reduced crop inputs should be achieved in order to improve the sustainability of the crop.

- Under the economic point of view, the results in Extremadura and other areas have shown the competitiviness of biomass sorghum compared to forage maize, due to its lower production costs (unos 79€/tDM compared to 125€/tDM for maize). The production costs are next to breakeven point for annual crop yields about 18tDM/ha, for a land rent cost about 500€/ha. The land renting and the biomass yields are the main factor affecting the economic viability of sorghum biomass production in Spain.

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Preliminary evaluation results of cardoon (*Cynara cardunculus L.*) in On Cultivos

Biomass yields of 5-20 t/ha after three years plantation. Implantation, crop development and biomass production yield very influenced by the edaphoclimatic conditions, particularly the rainfall at the beginning of the spring period.

Need for seeds selection and genetic improvement.

Improved clones obtained by meristematic in vitro growth are being developed and tested in On Cultivos.

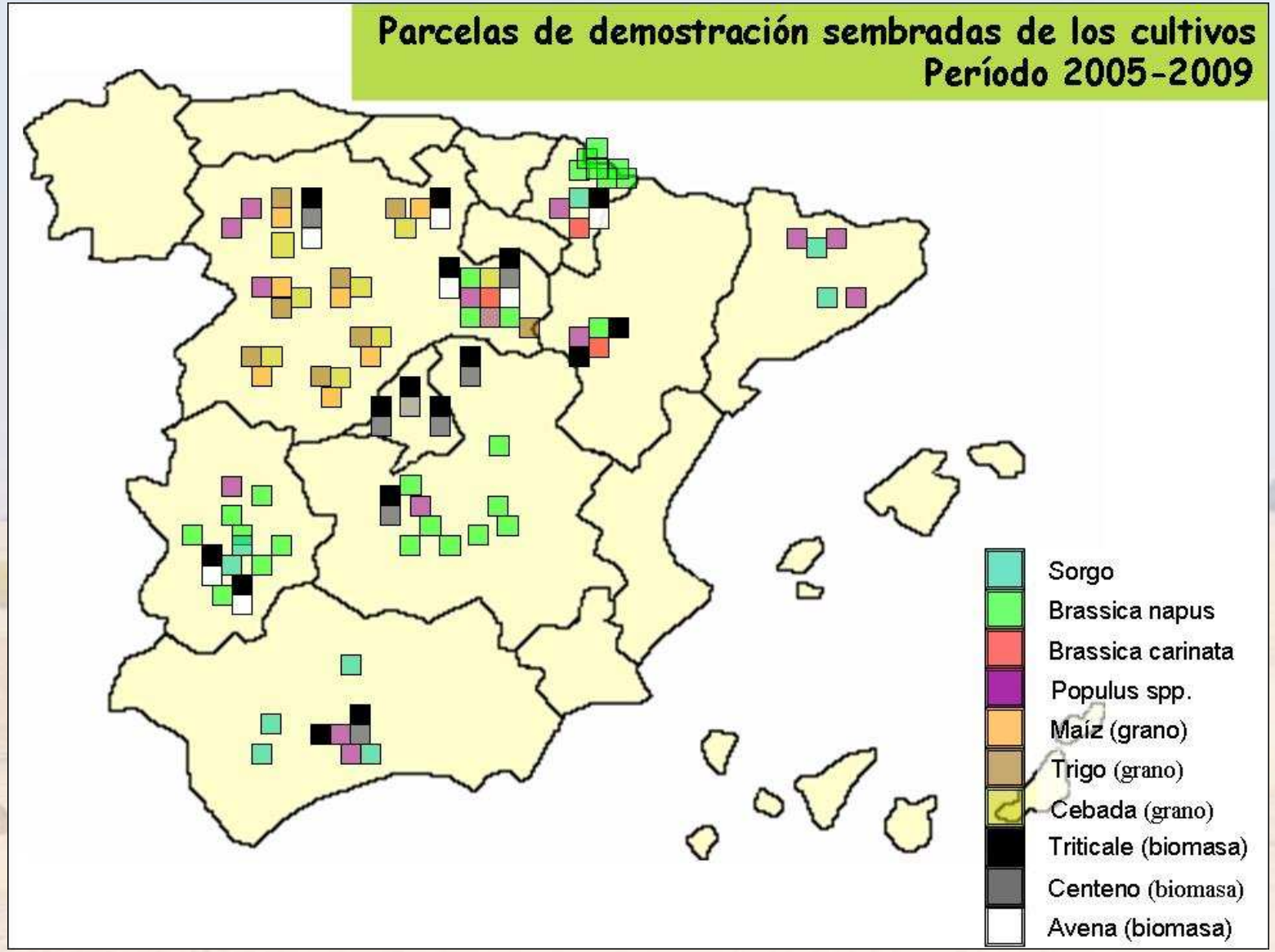
Mechanization of the harvesting is not well developed.

Taking into account the previous results, in 2009, a programme on new crops is started within On Cultivos with the purpose to give a sustainable response to the dry conditions of spanish agricultural lands as well as to reduce the water requirements in the irrigation conditions, thus contributing to their sustainability.

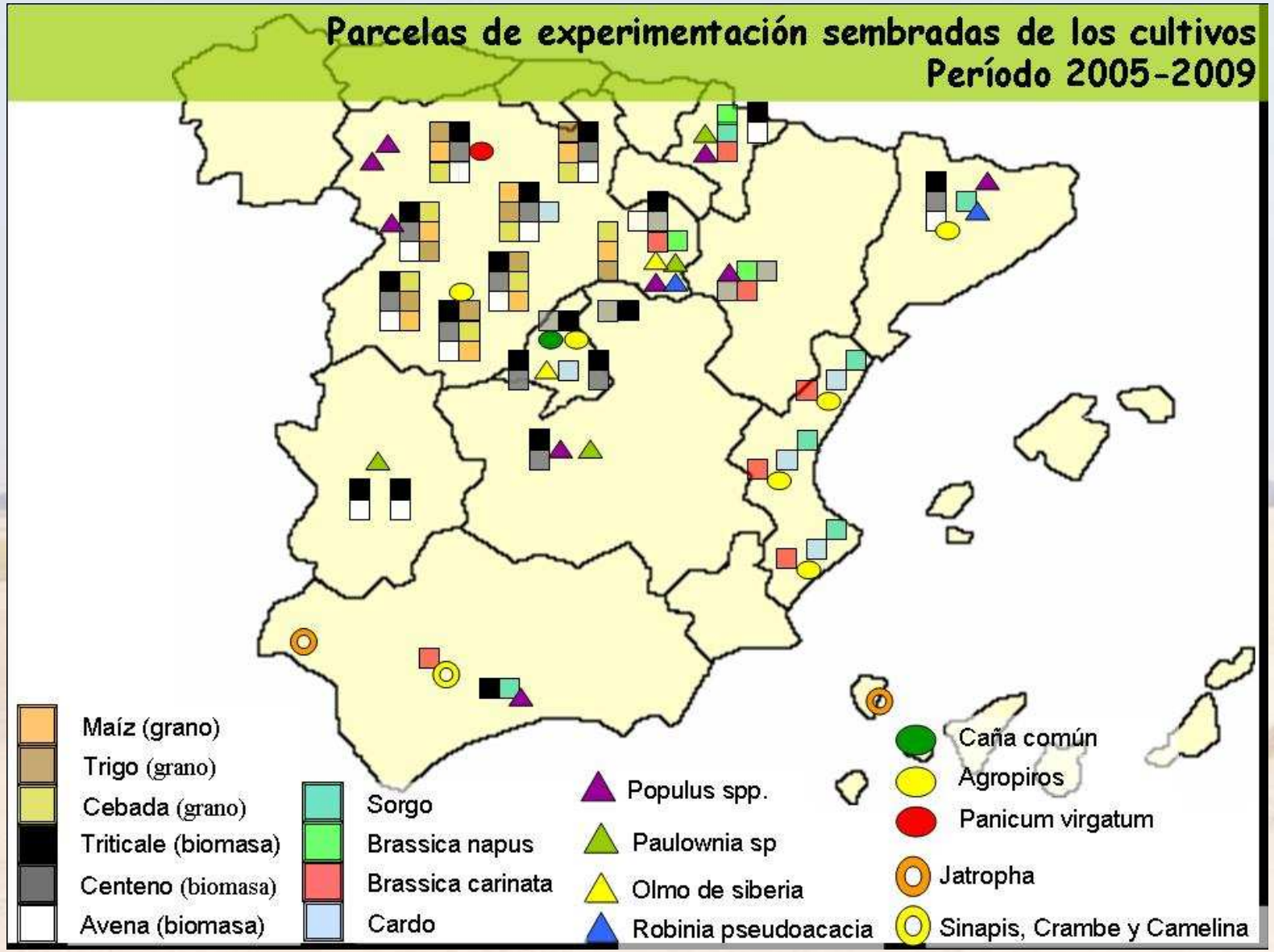
New crops started in 2009 in On Cultivos

Grasses for biomass	**<u>Annual</u>**	**<u>Perennial</u>**
	-Barley	-Panicum
	- Rye	- Andropogon
	- Oat	- Agropiros
		- Festuca
		-Arundo donax
Short rotation trees adapated to semiarid conditions	Robinia (*Robinia pseudoacacia)*	
	Siberian elm (*Ulmus pumila)*	

Demonstrative parcels in On Cultivos. Period 2005-2009



Experiemental parcels in On Cultivos. Period 2005-2009



Preliminary evaluation results of annual cereals for biomass in On Cultivos

Rye demonstrative parcel

Oat demonstrative parcel

Triticale demonstrative parcel

In 2009-2010 campaign,in general, the biomass yields have been triticale >centeno>avena, although a large variability among the different sites has been observed

Average triticosecale biomass yield: 5-10 t/ha

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ENSAYO DE ESPECIES C3. Albacete (España). Implantado 2010

Fecha fotos 1 año: 30 de septiembre de 2010

Panicum virgatum var. Blackwell
Altura aprox: 45cm

Panicum virgatum var. Cave in Rock
Altura aprox: 40cm

Panicum virgatum var. Alamo
Altura aprox: 90cm

Panicum virgatum var. NE28
Altura aprox: 40cm

Izquierda: Sorghastrum nutans var. Tomahawk (15cm)

Dcha: Panicum virgatum var. Sunburst (altura aprox. 45cm)

Andropogon gerardii var. Roundtree
Altura aprox: 45cm

Andropogon gerardii var. Sunnyview
Altura aprox: 40cm

Association of agropiro with leguminous. Pilar de la Horadada (Valencia) May 2011

In Spain, Panicum virgatum can reach up to about 1m height in the first year, with a production of about 6 tDM/ha

P. virgatum León
August 2010. First year

P. virgatum. Pilar de la Horadada (Valencia) September 2010

P. virgatum. Pilar de la Horadada (Valencia). May 2011

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ESTRATEGY FOR THE SUSTAINABLE INTRODUCTION OF ENERGY CROPS IN SPAIN (VIEW FROM ON CULTIVOS PROJECT)

Short term

Annual grasses in dry conditions and poplar and biomass sorghum under irrigation conditions for power production

Middle-long term

Predominantly perennial species (grasses and trees) in dry and irrigation conditions with progressive implementation of more sustainable- low inputs practices (direct sewing, association or rotations with leguminous…). Substitution of the initial especies for other with less water and fertilizer requierements and similar or improved profitability (e.g Forage sorghum by Panicum).

Why perennial species can take an advantage as energy crops in Spain and in the mediterranean areas?

- Some forage species (festuca, agropiro) are well adapted to the dry mediterranean conditions and have traditionally been used for forage production in these areas in the past and they show a good potential for biomass production. The tree species adapted to dry conditions has the advantage, as is the case for perennial grasses, to resist better than annual species the dry periods, and since they can give a more estable biomass production since they are not harvested annually.

- Perennial species produce a better soil protection against erosion caused by the rainfall, particularly the summer short and intense rains typical of the mediterranean area.

- The energy GHG savings seem to be higher with perennial than with annual species.

- Under spanish conditions, the preliminary calculations obtain breakeven points of the perennial crops within the expected production limits in many cases, although more reliable information about the crops growth conditions. and biomass yields is needed

Economic analysis of different herbaceous energy crops in Spain

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Vida util parcela		7		9		12		15		1
Detalle	Perennial Gr Dry		Perennial Gr. Fresh Dry		Perennial gr. Irrigation		Cardoon dry conditions		**Annual Cereal biomas**	
Unidades	U/ha	€/ha	U/ha	€/ha	U/ha	€/ha	U/ha	€/ha	U/ha	€/ha
Implantation costs										
Sews	18	126	20	140	14	98	8	400	140	114
Direct sewing	1	60	1	60	1	60	1	60	1	60
Herbicides+ applications	2	25	2	35	2	35	2	35	2	35
Fertilizers+ application	300	89	300	89	500	142	300	89	300	115,6
Total implantation costs. Year 0		300,2		324,2		335		584,2		324,6
Resewing		120		120		120		120		0
Maintennce costs										
Land renting		65		120		320		120		80
Fertiliers+ application	300	74,8	400	96,4	600	139,6	400	96,4	300	64,8
Harvesting		20		25		30		25		30
Rowing		12		17		35		17		12
Packing		100		120		160		120		120
Loading		10		15		30		15		25
Irrigation (inc water application y cost)	0	0	0	0	5000	**160**	0	0	0	
Total annual maintenance		281,8		393,4		874,6		393,4		331,8
Total implant.+ maint. during crop lyfe cicle		2233,4		3784,6		10655,4		6405		656,4
Incomes										
Annual biomass yield (tDM/ha)		**6**		**9**		**15**		**9**		**8**
Prize of biomass (€/t.MS)		85		85		85		85		85
Total annual income (€/ha)		510		765		1275		765		680
Biomass production during the crop life cycle		36		72		170		117		680
Total income during crop life cycle		3060		6120		14450		9945		680
Gross margin (crope life cycle)		827		2335		3795		3540		23,6
Gross annual margin (€/ha)		**118**		**259**		**316**		**236**		**23,6**
Biomass production cost (€/tDM)		**53,2**		**46,7**		**59,2**		**47,4**		**82,1**
Breakeven point (tDM/ha.year)		**4,4**		**5,6**		**11**		**6**		**7,5**

**** Supuestos del cálculo***

1) Rendimientos expresados en toneladas de materia seca por hectárea (tMS(ha) según experiencias previas y datos publicados en España (CITA). El primer año se considera cero rendimiento, menos en el regadío donde se considera un rendimiento de 5tMS/ha en el año de establecimiento
2) Costes de regadío: 0,021€/m3 como coste de bombeo y un canon fijo de 40€/ha.año
3) Los costes de siega, hilerado y empacado varían según el rendimiento. Se han tomado experiencias de On Cultivos
4) El rendimiento de las perennes de secano el primer año se considera demasiado bajo y se incorpora como abono verde (en el regadio se asumen 5tMS/ha)
5) Se ha tomado MCPA (herbicida malas hierbas latifoliadas) a un coste de 18,35€/lt y 1lt/ha de dosis
6) El primer año en perennes, el abono de cobertura posee media (50%) dosis por una baja expectativa de rendimiento
7) el precio de referencia considera base hçumeda (bh) de 11% en la biomasa entregada y se expresa en € por tonelada de materia seca
8) Se ha considera en perennes una renovacion de la plantacion (resiembra para rejuvenecimiento, con siembra directa y abono de sementera) a la mitad de la vida util

Indicative (expected) production costs of different energy crops in Spain. Reference biomass prize for electricity production:80-85€/tMS

Crop	Implantation conditions	Biomass production tMS/ha.year	Production Cost €/tMS	Remarks
Poplar	Irrigation	15-20	55-60	Land rent. 380€/ha.year
Sorghum biomass	Irrigation	18-22	70-75	Land rent. 380€/ha.year
Triticale-rye	Dry fresh	7-12	50-85	Land rent. 120€/ha.year
Cardoon	Dry- semiárid	10	50-55	Crop lifecycle 10 years. No production the first two years. Land rent 120€/ha.year
Perennial grasses (festuca, agropiro, phalaris…)	Dry fresh	7	64	Crop lyfecicle 9 years Resewing by direct sewing at year 4
	Dry semiarid	5,5	61	Crop lyfecicle 9 years Resewing by direct sewing at year 4
	Irrigation	12	82	Crop lyfecicle 12 years Resewing by direct

Correlation between economic and energy ratios of Different energy crops and energy applications

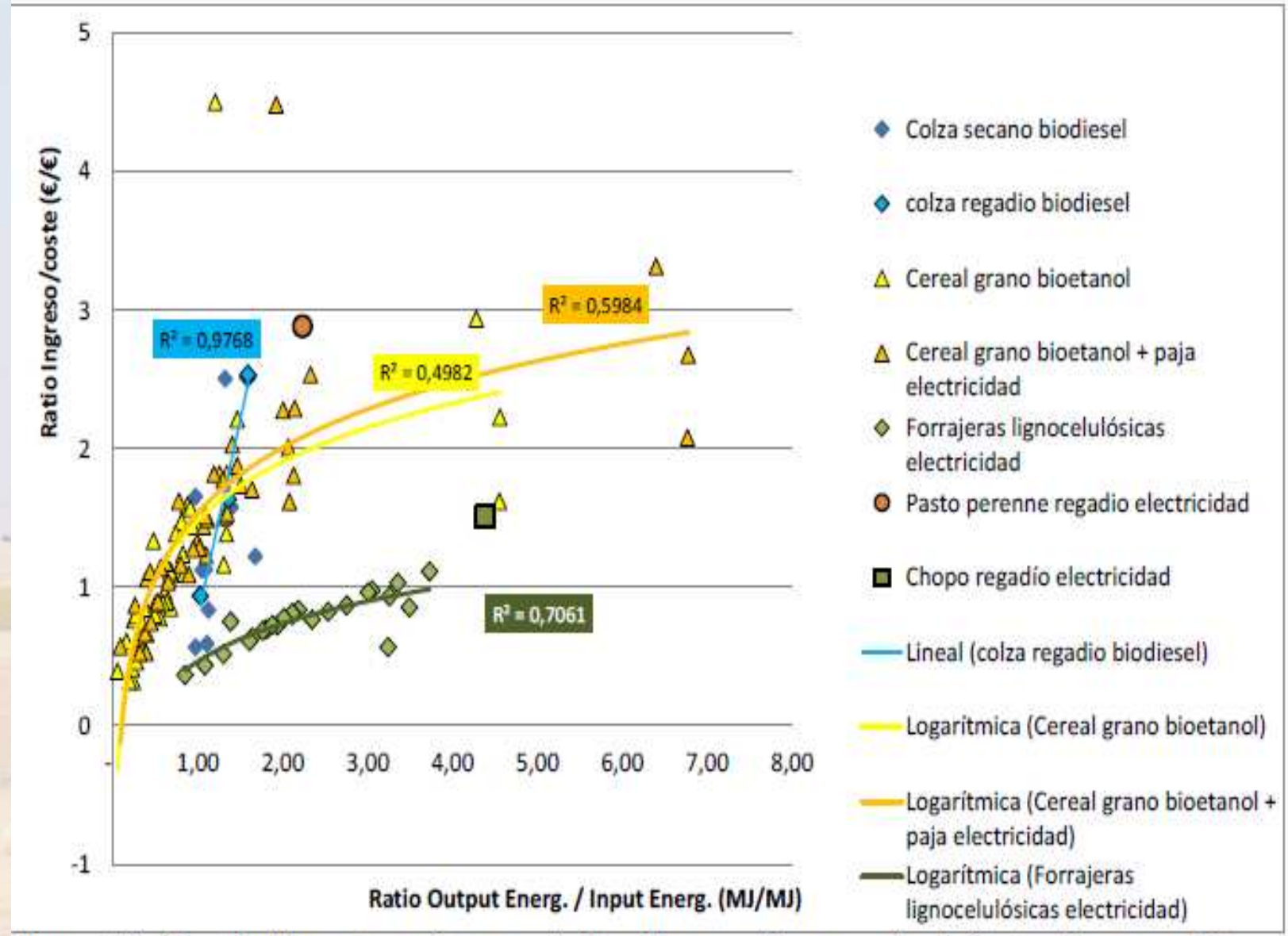

Figura 22: Correlación entre ratios económico (Ingreso fase agraria / Costes fase agraria) y energético (output/input) de los cultivos considerados

Average inputs and GHG savings compared to fossil fuels of reference of different energy crops biomasses in Spain. Rapeseed and cereals for liquid biofuels and the rest for electricity production, respectively.

Contepto	Unidades	Estadistico	Colza secano	Colza riego	Cereal grano	Cereal grano+paja	Forrajeras anuales	Pasto perenne	Chopo
Uso agua	m3/ha	media	0	416	0	0	0	1200	3000
		desv	0	479				-	-
		CV	0	1,2				-	-
Uso de N	kg/ha	media	111	123	143	143	112	120	67,5
		desv	60,2	58,5	25,5	25,5	27,6	-	-
		CV	0,5	0,5	0,2	0,2	0,2	-	-
INPUT ENERGIA	MJ/ha	media	21138	20375	54536	55245	14257	28395	85170
		desv	7084,4	10983,3	39504,1	39338,4	3286,7	-	-
		CV	0,3	0,5	0,7	0,7	0,2	-	-
OUTPUT ENERGIA	MJ/ha	media	29156	36499	31277	51307	30987	63374	373445
		desv	0,3	0,6	0,2	0,2	0,9	-	-
		CV	0,0	0,0	0,0	0,0	0,0	-	-
O/I	MJ/ha	media	1,35	1,73	0,95	1,49	2,26	2,23	4,38
		desv	0,2	0,3	1,1	1,6	0,8	-	-
		CV	0,1	0,2	1,1	1,1	0,3	-	-
Ahorro GEI	%	media	33%	50%	-5%	26%	56%	78%	62%
		desv	0,16	0,18	0,42	0,20	0,16	-	-
		CV	0,5	0,4	-7,8	0,8	0,3	-	-

GHG savings (%) with respect to reference fossil fuels of different energy crops yields in Spain

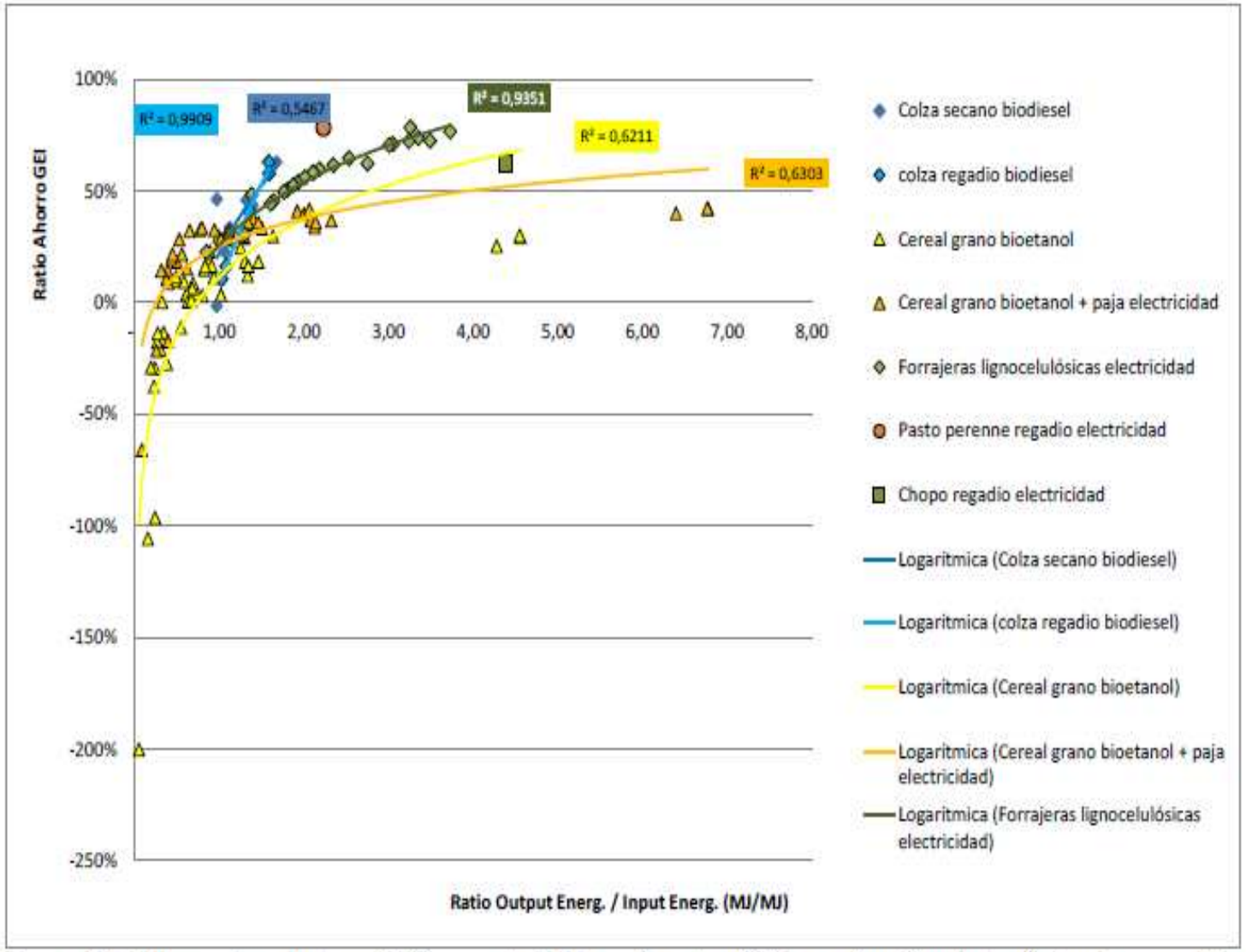

Figura 23: Ahorro de emisiones (%) respecto de los referentes fósiles en función de la eficiencia energética en todos los cultivos considerados.

Implicaciones de las políticas actuales sobre la producción de energía a partir de la biomasa de cultivos energéticos en España

-En España la producción de cereales y de oleaginosas para producción de biocarburantes presenta pocas posibilidades bajo un punto de vista económico y de cumplimiento de los requisitos de ahorro de emisiones de efecto invernadero (GHG) por el uso de biocarburantes exigidos por la RED:

- 35% ahorro mínimo de emisiones de GHG respecto a combustibles fósiles en 2010
- 50% de ahorro mínimo de emisiones GHG en 2017
-60% de ahorro mínimo de emisiones GHG en 2018

Estos requisitos , principalmente los mas restrictivos son difíciles de cumplir con las producciones españolas de oleaginosas y cereales grano.

-La producción de cultivos lignocelulósicos para generación eléctrica es una alternativa mas sostenible que la anterior y en determinados casos puede ser ya rentable respecto a los cultivos tradicionales

- precio de referencia actual para la biomasa para generación eléctrica (grano+paja): 80-85€/t MS