Co-design and multicriteria assessment of low-input cropping systems in the South-West of France: a 8-years experimentation with farmers

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Introduction

Food production in the last decades has been greatly increased thanks to intensification of agriculture but this intensification also led to numerous undesirable environmental impacts such as biodiversity loss, soil degradation, and soil, water, air, and food contamination by pesticides (Foley *et al.*, 2005; MEA, 2005). Moreover, in many cases, economical performances of intensive cropping systems (CS) decreased that weakens the sustainability of farms. In the South-West of France, two main traditional CS could be identified: a rainfed durum wheat-sunflower CS and a maize monoculture CS (mainly irrigated). The main objective of this study was to evaluate the sustainability of CS designed as alternatives of these two traditional CS that aimed at reducing the negative externalities of agriculture while answering specific objectives of the involved farmers.

Table 1. Main characteristics of the 8 farms involved in the study. B: barley; CS: carrot seed; DW: durum wheat; FB: Fababean; M: maize; MS: maize seed; RS: rapeseed; SB: soybean; SG: sorghum; SF: sunflower; SW: soft wheat.

Site (department number)	Soil type	Initial CS	Alternative CS
Farm 1 (09)	Silt – Clay silt	MS monoculture	MS → MS → SF → SW → SB → SW
Farm 2 (31)	Silty with coarse elements, hydromorphic	M monoculture	M → SW → SB
Farm 3 (65)	Silt with coarse elements	M monoculture	M → SF → SW → SB → SW
Farm 4 (65)	Silt with coarse elements	M monoculture	M → SB → SW
Farm 5 (31)	Silt with coarse elements, hydromorphic	M → SW	M → SW → CS → SW → RS → SW
Farm 6 (31)	Calcareous clay on hillsides	DW → SF	DW → SF → SW → SG
Farm 7 (46)	Calcareous clay on hillsides	RS → SW → B	RS → SW → SF → B
Farm 8 (81)	Calcareous clay on hillsides	DW → SF → SW → SF	DW → SG → SB → SW → SF → FB → SW → SF

Materials and methods

Workshops, mixing farmers, advisers and scientists, were organized in 2009 and 2010 in order to (i) identify strengths and weaknesses of initial CS; (ii) design alternative CS (based on formalized decision rules) in order to answer to common and specific objectives; (iii) define/choose the indicators to monitor the CS performances and, after an *ex-ante* assessment (iv) experiment and perform an *ex-post* evaluation of the designed CS for each involved farm (Papy, 2001; Debaeke *et al.*, 2009). A 8-farms network was involved in this 8-years study (2010-2017) (Table 1). The main indicators chosen to monitor performances are mentioned in Table 2.

Table 2. List of selected indicators for cropping system performance assessment.

Dimension	Criteria	Indicator
Economic	Profitability	Semi net margin (SNM) at rotation level (€/ha)
Economic	Weed management	Weed abundance in the field
Economic	Dependency on external inputs	Input use efficiency
Economic	Productivity	Energetic yield (MJ)
Environmental	Water quality (pesticide)	Treatment Frequency Index (TFI)
Environmental	Water quality (pesticide)	I-phy
Environmental	Water quality (pesticide)	Number of toxic pesticides for aquatic systems
Environmental	Water quality (nitrate)	Nitrogen indicator (NI)
Environmental	Water quantity	Irrigation amount (m^3/ha)
Environmental	Soil quality	Organic matter indicator (IMO)
Environmental	Soil quality	Length of bare soil period (%)
Environmental	Fossil energy	Total fuel consumption at CS level (MJ/ha)
Environmental	Climate change mitigation	GHG emission (equivalent t CO_2/ha)
Social	Farmers' quality of life	Labor time (h/ha)
Social	Farmers' quality of life	Workload distribution (h/ha/month)
Social	Famer and public health	Number of pesticide applications

Furthermore, in order to test the robustness of cropping systems, 8 crop price scenarii, chosen over the period 2007-2014, were applied and a comparison between the economic performances of the initial CS and the alternative CS was made.

Results and discussion

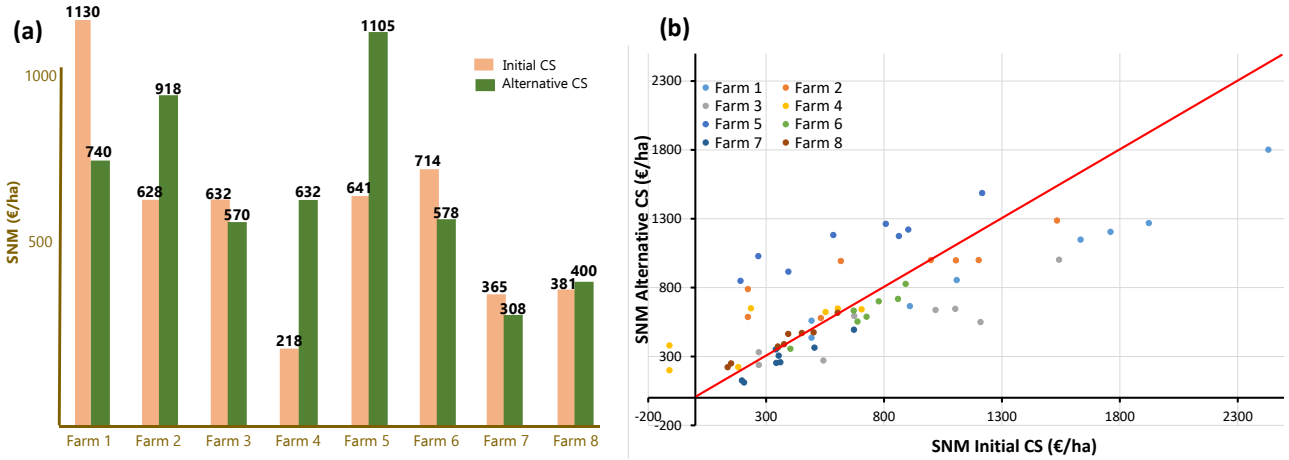

Fig. 1. Semi net margin (a) and robustness toward crop price fluctuations (b) of initial and alternative CS.

Crop diversification was found to enhance CS economical performances if associated with rigorous control of the mechanization loads (Fig.1a). In most cases, diversification led to a better distribution of workload during the year allowing the development of high added value production (such a vegetables with direct selling). Selected indicators illustrated that diversification could lead to lower environmental impacts (Table 3), except if seed production (with high pesticide use) was integrated in the CS. For the project DiverIMPACTS, further investigations are performed with economical stakeholders to increase economical performances of diversified CS. In parallel, a multicriteria assessment (using the indicator list of DiverIMPACTS) of the initial (mainly maize monoculture) and diversified CS of the 20 farms involved in the Case Study 5 has started and should strengthen conclusions on the effects of crop diversification on the sustainability of South-West of France farms.

Table 3. Multicriteria assessment of alternative CS (selected indicators from the list of Table 2)

	SNM	TFI	NI	GHG	Labor time	Farmer satisfaction
Farm 1	-35%	-39 %	+43%	-21 %	-67 %	↘SNM
Farm 2	+46%	-62%	0%	0%	-72%	↘TFI; ↗SNM; ↘Labor time + Conservation agriculture
Farm 3	-10%	-16%	0%	-17%	-37%	↘Labor time + diversification in vegetable production
Farm 4	+189%	+25%	+156%	-62%	-45%	↘Labor time + Conservation agriculture; better weed management
Farm 5	+72%	+71%	+15%	-17%	0%	↗TFI (seed contract); ↗SNM
Farm 6	-20%	-48%	+32%	+24%	+25%	Better weed management
Farm 7	-15%	+10%	+24%	-30%	0%	Better weed management; low SNM
Farm 8	+5%	-43%	+47%	-43%	+10%	↗Labor time; Better weed management

References

Debaeke, P., Munier-Jolain, N., Bertrand, M., Guichard, L., Nolot, J.M., Faloya, V., Saulas, P., 2009. Iterative design and evaluation of rule-based cropping systems: methodology and case studies. A review. Agronomy for Sustainable Development 29, 73-86.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N., Snyder, P.K., 2005. Global consequences of land use. Science 309, 570-574.

MEA, M.E.A., 2005. Millennium Ecosystem Assessment Synthesis Report. Island Press, Washington DC.

Papy, F., 2001. Interdépendance des systèmes de culture dans l'exploitation. In: Malézieux, E., Trébuil, G., Jaeger, M. (Eds.), Modélisation des agroécosystèmes et aide à la décision. CIRAD-INRA, pp. 51-74.