Maintaining soil quality: an issue for the profitability and sustainability of farms

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Research question

- **2050: 9 billion people → increase in agricultural production**
- Two possible answers : increase in agricultural land proportion or **increase in agricultural land productivity** …
- … while considering environmental issues and impacts, in a context of increasing energy and fertilizers prices
- To do so : **Ecologically Intensive Agriculture**, which consists in increasing **natural resources productivity** through the use of ecosystem functions in a **long-term perspective** with, in particular, practices **maintaining/enhancing soil quality** in order to increase soil productivity
- But...

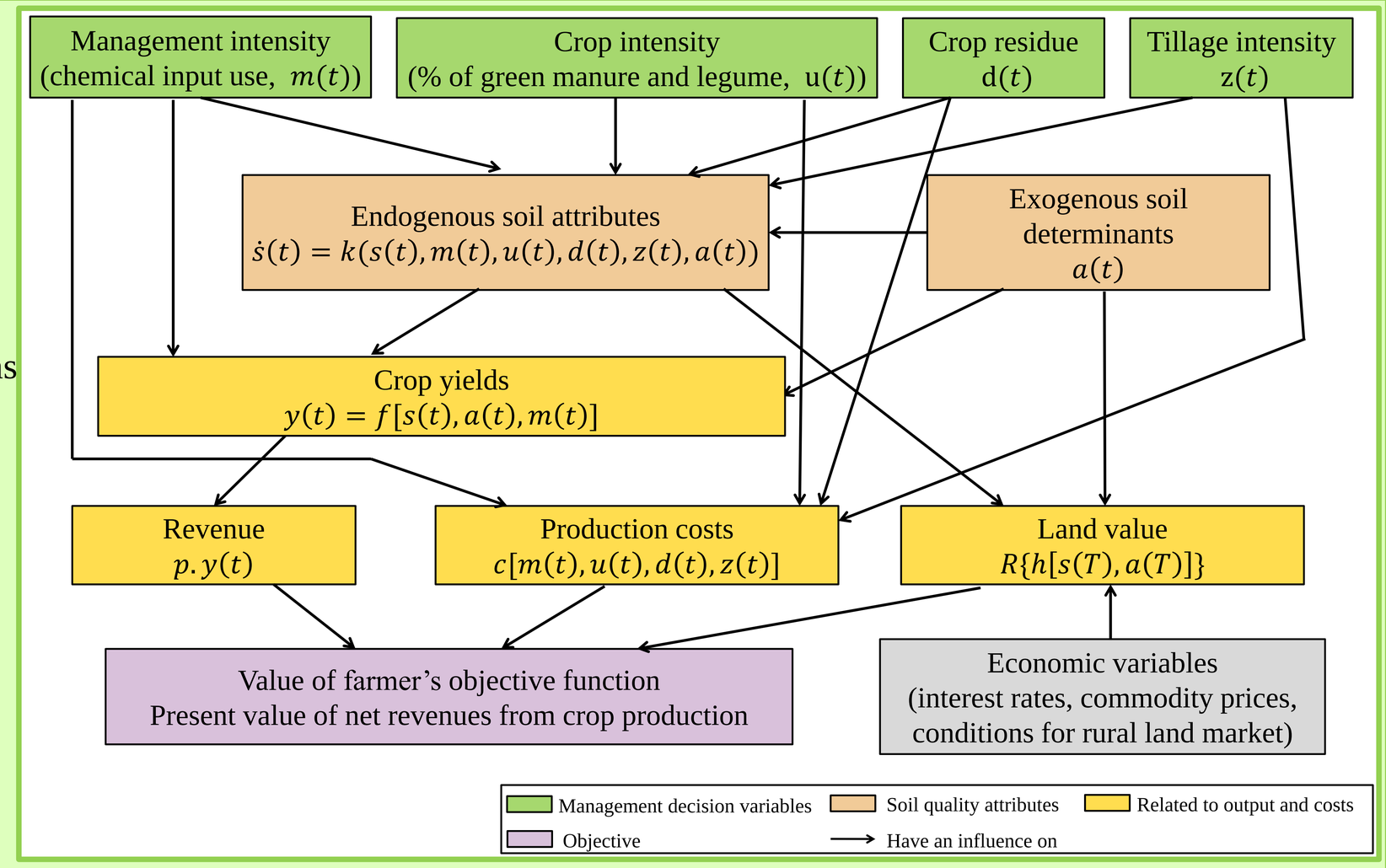
Are soil conservation related practices optimal in terms of farms profitability and sustainability ?
→ Soil quality optimal control model

Material and Methods

- **Elaboration of a comprehensive farm-level soil quality model**

- **Calibration of 2 functions**:
production function and soil organic carbon (SOC) dynamics function using farming practices data, soil quality indicators and climatic conditions
BUT not enough data to estimate consistent and significant coefficients

- **Application of the model: example of the Canadian Great Plains**
A wheat producer farmer, owner of his land, maximises his revenue :



$$\max_{N,P,Z} \int_0^T e^{-rt}[pf(N(t),P(t),OC(t)) - c_1 N(t) - c_2 P(t) - c_3 Z(t)]dt + e^{-rT} R\{h(OC(T))\}$$

Subject to:

$$\dot{OC}(t) = k\big(N(t), Z(t)\big) \quad \text{Soil quality motion}$$
$$0 \le Z(t) \le 1 \quad \text{Bounds on tillage intensity}$$
$$0 \le N(t) \le N_{max} \quad \text{Bounds on N fertilizers inputs}$$
$$0 \le P(t) \le P_{max} \quad \text{Bounds on P fertilizers inputs}$$

with **production function from Smith et al (2000):** quadratic function representing the impacts of N and P fertilizers, SOC, inorganic carbon, soil pH, soil electric conductivity and precipitations on wheat yield, as well as the cooperating relationships between the different parameters

and **SOC dynamics function from Halvorson et al (2002):** considering the impacts of tillage intensity and N fertilizer input intensity on SOC

Results

Optimisation	N(kg/ha)	P(kg/ha)	Tillage	Estimated yields (kg/ha)	Estimated profit (€/ha)
Without considering SOC dynamics	133.274	64.847	0	4351.007	455.985
Without considering SOC dynamics and with conventional tillage practice	133.274	64.847	1	4351.007	430.185
Considering SOC dynamics*	11.002	0	0	4032.838	493.514
Considering SOC dynamics and practicing conventional tillage **	-	-	1	-	-
Baseline scenario (Smith et al, 2000)***	83	43	1	4066.567	424.950

*At steady state
** No solution found
*** With the average values of applied mineral N and P of Smith et al (2000) and considering a maximum intensity of tillage (conventional tillage)

Conclusion and Perspectives

- At steady state: **zero-tillage + low fertilizers inputs**
- **Considering SOC dynamics**: higher profit → **provide valuable information**
- Suggest that **soil quality dynamics have a significant role in the profitability and sustainability of farms**
- Basis to a more complex modelling of soil quality dynamics role in farms profitability and sustainability, including the role of prices, investment costs, labour costs, time costs, risk and uncertainty and other factors (climatic…)

References

- Smith E.G., Lerohl M., Messele T. and Janzen H.H., 2000. *Soil Quality Attribute Time Paths: Optimal Levels and Values.* Journal of Agricultural and Resource Economics. Vol. 25, N°1, pp. 307-324
- Halvorson A.D., Wienhold B.J. and Black A.L., 2002. *Tillage, nitrogen and cropping system effects on soil carbon sequestration.* Soil Science Society of America Journal. Vol. 66, N°3, pp. 906-912