“A modelling approach for assessing environmental and economic impacts of agri-environmental schemes (AES) to enhance soil C sequestration and reduce pollution risks”

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Rationale of the study

• Chemical fertilizers are responsible for air, soil and water pollution
• Use of organic amendments can limit the use of chemical fertilizers
• Adoption of organic amendments is low although agri-environmental schemes (AES): why and how to improve?
Objectives

- Simulating with a crop model several scenarios of fertilization over a 10-years period, for several farm types
- Multi-criteria assessment: crop yield; nitrate leaching; C sequestration; net income
- Proposing best practices and agri-environmental policies, accounting for diversity of farms and adoption constraints
Simulated scenarios of fertilization

**NFER scenario:** inorganic N fertilizer applied at a rate of 200 kg N ha\(^{-1}\) yr\(^{-1}\)

**AES\(_{\text{old}}\) scenario:** organic amendment applied as compost at a rate of 15 Mg fresh matter ha\(^{-1}\) yr\(^{-1}\) (equivalent to 80 kg organic N ha\(^{-1}\) yr\(^{-1}\)) + 900€/ha/yr

**AES\(_{\text{new}}\) scenario:** organic amendment applied as compost at a rate of 7 Mg fresh matter ha\(^{-1}\) yr\(^{-1}\) (equivalent to 37 kg organic N ha\(^{-1}\) yr\(^{-1}\)) and N fertilizer applied at a rate of 150 kg N ha\(^{-1}\) yr\(^{-1}\) + 900€/ha/yr

**SLUD scenario:** organic amendment applied as sewage sludge at a rate of 20 Mg fresh matter ha\(^{-1}\) yr\(^{-1}\) (equivalent to 190 kg organic N ha\(^{-1}\) yr\(^{-1}\)).
Methodological framework

- Case study: yam production in Guadeloupe, compost and sewage sludge use, acid ferralsols (C content < 20mgC/kg)

1. Definition of 4 scenarios: NFER, AESold, AESnew, SLUD
2. Assessment of humification factors of organic amendments
3. Simulation of the soil-yam system with CropSyst-Yam
4. Calculation of economic indicators
5. Estimate of the impact of the farm size
Modelling of yam growth and yield
(Marcos et al., Eur. J. Agron., 2011)

CropSyst-Yam includes a sub-model of yam development and a sub-model of growth adapted from CropSyst-potato (Stöckle et al., Eur. J. Agron., 2003)

- Yam development is described as a function of air temperature and photoperiod, based on 15 field experiments carried out in Guadeloupe (Marcos et al., Field Crops Res. 2009)
- Calibration and test were performed using data from 9 field experiments carried out in Guadeloupe

Total dry matter: obs ●, model — ; Tuber dry matter: obs ●, model — ; LAI: obs ●, model —

Yam growth and tuberisation are strongly affected by photoperiod for planting dates after July
Results: N leaching (kg N ha\(^{-1}\))

**NFER**: inorganic N fertilizer (200 kg N ha\(^{-1}\) yr\(^{-1}\))

**AES\(_{\text{old}}\)**: organic amendment compost (15 Mg ha\(^{-1}\) yr\(^{-1}\)) + subsidy 900 € ha\(^{-1}\) yr\(^{-1}\)

**AES\(_{\text{new}}\)**: organic amendment compost (7 Mg ha\(^{-1}\) yr\(^{-1}\)) and N fertilizer (150 kg N ha\(^{-1}\) yr\(^{-1}\)) + subsidy 900 € ha\(^{-1}\) yr\(^{-1}\)

**SLUD**: organic amendment sewage sludge (20 Mg ha\(^{-1}\) yr\(^{-1}\)).
Results: C sequestration over 10 years (kg C ha\(^{-1}\))

**NFER**: inorganic N fertilizer (200 kg N ha\(^{-1}\) yr\(^{-1}\))

**AES\(_{\text{old}}\)**: organic amendment compost (15 Mg ha\(^{-1}\) yr\(^{-1}\)) + subsidy 900 € ha\(^{-1}\) yr\(^{-1}\)

**AES\(_{\text{new}}\)**: organic amendment compost (7 Mg ha\(^{-1}\) yr\(^{-1}\)) and N fertilizer (150 kg N ha\(^{-1}\) yr\(^{-1}\)) + subsidy 900 € ha\(^{-1}\) yr\(^{-1}\)

**SLUD**: organic amendment sewage sludge (20 Mg ha\(^{-1}\) yr\(^{-1}\)).
Results: net income (€ ha\(^{-1}\))

- **NFER**: inorganic N fertilizer (200 kg N ha\(^{-1}\) yr\(^{-1}\))
- **AES\(_{\text{old}}\)**: organic amendment compost (15 Mg ha\(^{-1}\) yr\(^{-1}\)) + subsidy 900 € ha\(^{-1}\) yr\(^{-1}\)
- **AES\(_{\text{new}}\)**: organic amendment compost (7 Mg ha\(^{-1}\) yr\(^{-1}\)) and N fertilizer (150 kg N ha\(^{-1}\) yr\(^{-1}\)) + subsidy 900 € ha\(^{-1}\) yr\(^{-1}\)
- **SLUD**: organic amendment sewage sludge (20 Mg ha\(^{-1}\) yr\(^{-1}\)).
Conclusions

- NFER is the most profitable strategy but leads to high nitrate leaching and low C sequestration.
- Old AES is the less profitable strategy → low adoption by farmers.
- SLUD use lead to best C sequestration but N leaching.
- The characteristics of the organic amendments, the rainfall level and the farm type, affect performances of the AESs.
Practical implications

✓ The **new AES**, which combines organic and inorganic inputs, could promote C sequestration and reduce the risks of nitrate pollution, while maintaining net income (after a transition period of 5-6 years)

✓ AES adoption by large farmers needs the implementation of mechanical application of compost to reduce labour costs.
Thank you for your attention!