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Research article

The PRECOS framework: Measuring the impacts of the global changes on soils, water, agriculture on territories to better anticipate the future

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ABSTRACT

In a context of increased land and natural resources scarcity, the possibilities for local authorities and stakeholders of anticipating evolutions or testing the impact of envisaged developments through scenario simulation are new challenges.

PRECOS's approach integrates data pertaining to the fields of water and soil resources, agronomy, urbanization, land use and infrastructure etc. It is complemented by a socio-economic and regulatory analysis of the territory illustrating its constraints and stakes. A modular architecture articulates modeling software and spatial and temporal representations tools. It produces indicators in three core domains: soil degradation, water and soil resources and agricultural production.

As a territory representative of numerous situations of the Mediterranean Basin (urban pressures, overconsumption of spaces, degradation of the milieus), a demonstration in the Crau's area (Southeast of France) has allowed to validate a prototype of the approach and to test its feasibility in a real life situation. Results on the Crau area have shown that, since the beginning of the 16th century, irrigated grasslands are the cornerstones of the anthropic-system, illustrating how successfully men's multi-secular efforts have maintained a balance between environment and local development. But today the ecosystem services are jeopardized firstly by urban sprawl and secondly by climate change. Pre-diagnosis in regions of Emilia-Romagna (Italy) and Valencia (Spain) show that local end-users and policy-makers are interested by this approach. The modularity of indicator calculations and the availability of geo-databases indicate that PRECOS may be up scaled in other socio-economic contexts.

1. Introduction

Present crisis and transitions all have in common that they

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concern primary production fields (agriculture, raw materials), transformation activities (industry and crafts) and local economy (retail, general services and transport…) (Pachauri and Reisinger, 2007; IEA, 2008). They impact land use and resources (water, food and energy) and they are mutually interdependent. Thus the gradual awareness of the "crisis" dimension leads to a renewed approach of resources and regional areas' management systems (World Bank, 2007, 2009; FAO, 2009; Trolard and Dangeard, 2014). To face these challenges, efforts should focus on:

- Capacity building in relationship to territorial analysis at different organizational levels. Systemic analysis (Saritas and Oner, 2004), life-cycle analysis (Day, 1981; Ayres, 1995; Ayres et al., 1998; Von Bahr and Steen, 2004) and integrative concepts (biophysical, biological indicators, ecological footprint, virtual water…) (Bell and Morse, 2004; Graymore et al., 2008) already are a dominant trend of recent literature (Bouman et al., 1999; Crescenzi et al., 2007; Davodi, 2012);
- Reinforcing expertise provision in different but complementary disciplines, such as support for the shaping and monitoring of public policies, critical assessment and dissemination of references or devising innovations with attention to their social acceptability;
- Merging and/or adapting technological innovations from other sectors in order to develop new analysis or expertise tools for territorial development (*e.g.* energy network models to assess cumulative environmental impact of urbanization on carbon emission (Chen and Chen, 2012) or on river ecosystems (Chen et al., 2015). Recent innovation in spatial metrology both in the fields of robotics and of information and communication technologies, now makes it possible to propose new management practices, assessment, monitoring and decision support tools (Xia Li and Gar-On Yeh, 2000; Waddel, 2002; Vohland and Barry, 2009…).

Cities, as they develop, have a tendency to degrade environmental assets, and impair the essential services provided by ecosystems. The difficulty resides in the evaluation of benefits provided by natural and agricultural areas. The changes thus introduced by urban development in the agro- and ecosystems increase the risks and retroactively impact the value of constructible land and of property because of regulation constraints (extension of non-constructible surfaces) and/or conditions attached to the safeguarding of investments (insurance, cost of loans….).

Cities are drivers for innovation (Glaeser, 2011) and urban growth is a productivity factor, enabling producers from rural areas, consumers and companies to access markets and the workforce to find employment. Hence, a first series of studies undertaken by ECOLOC (Club Sahel and OECD, 2001) has established that the concept of local economy ought to coincide with a tangible reality, for instance that of a pilot economic zone – always open towards other areas, regions, countries, world – but populated enough and with activities that are sufficient for having the potential for generating value and commercial exchanges.

Urbanization develops mainly at the expense of agricultural land at the outskirts of cities (Chakir and Madignier, 2006; Ruellan, 2010; Sapoval, 2011) and along coastal areas (Pageaud and Carré, 2009). For the moment, assessing the consequences of urban sprawl basically boils down to measuring surfaces consumed; it does not take into account the qualitative properties associated to soils and associated environmental functions before sealing.

To overcome such contradictions, it is necessary to identify the impacts of urban and agricultural policies over natural environments, to assess externalities and anticipate evolutions.

The PRECOS framework allows for simulating the likely evolution of indicators in the future and, in the light of various constraints, assessing the deterioration risks of local environmental assets and the lessening of decision makers' means and levers for potential action.

The main goal of this paper is to present the different elements of this approach highlighted by results obtained on the demonstration area, the Crau (South of France) with the prototype (Astuce & Tic, 2011) and some elements for structuring it in a framework (the PRECOS approach) applicable in other geo-socio contexts.

2. Methods

2.1. The basic concept

The basic idea is that urban sprawl cannot be considered separately from its immediate rural environment, *i.e.* its hinterland (Trolard et al., 2010; Trolard et al., 2013b). The circular causality chain DPSIR (Drivers – Pressure – State – Impact – Response) elaborated by the OECD (2003) is the working basis of the framework: human activities exert pressures over the environment and modify the quality and quantity of natural resources. Society reacts to these changes by adopting protection, limitation, confinement, depollution measures … and the cycle starts over again. The objective is of course to prompt a virtuous cycle.

2.2. Devising the software's architecture

The fields covered by the PRECOS approach comprise land occupation changes, soil sealing levels, agronomic qualification of soils, water geo-chemistry, fresh water needs according to the availability of resource and agricultural production requirements (Fig. 1a).

The selected models have already proven their efficiency in their respective fields. PRECOS integrates them all in an overall scheme (Fig. 1b), ensuring a global approach.

Both METRONAMICA (White and Engelen, 1993; White et al., 1997; Straatman et al., 2004) and URBANSIMUL (Géniaux, 2011) compute land occupation changes over time. In METRONAMICA, this transformation is achieved by the use of a cellular automaton coupled with a GIS, which constraints are defined by urbanization (distance to water, electricity networks, transport infrastructures …). URBANSIMUL uses probability tests of mutation of plots into urbanization based on tax data. The parameters, obtained from the analysis of the results of both software, measure and represent the territory of a land use conversion into another (natural, agricultural, urban and/or industrial areas and infrastructures), the share of coastline affected by urbanization and fragmentation of natural areas.

The method of Assessment of Soil Artificialisation (MEAS) (Astuce & Tic, 2011) takes into account the diversity and agronomic qualification of soils (SQI) (Balestrat et al., 2011), soil sealing and urban sprawl, including the fragmentation of agricultural lands. This approach is complemented by the EVA3 software (developed at Lausanne University) assessment of polluted sites and soils, which estimates the risk of soil contamination by industrial activities. MEAS and EVA produce spatially distributed typologies of artificial soil as well as input data for METRONAMICA or URBANSIMUL.

STICS (Brisson et al., 2003; Brisson, 2008) is a crop model that simulates crop biomass production, agricultural yields, water and nitrogen requirements, surface water flows and drainage (water percolation below the root zone). Calculations are made at the field plot level and aggregated on the territory with MultiSimLib model (Buis et al., 2011). The model is driven by climate parameters, which