Understanding agricultural ecosystem services with ARIES (ARtificial Intelligence for Ecosystem Services): Perspectives for assisted policy making

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Introduction

Agricultural practices depend on ecosystem services (ES; Farber *et al.*, 2006) and at the same time produce new ecosystem services. Because the dynamics, spatial and temporal scales, and range of values of ecosystem services production and usage are not well understood, it is difficult to locate agriculture within a broader context of ecosystem services-informed policy making. As a result, agricultural policy making often lacks understanding of the short- and long-term repercussions of decisions taken on the overall portfolio of valuable services produced by nature and necessary for human well-being.

ARIES (Ecoinformatics Collaboratory, 2008) is a new methodology and web application meant to assess ecosystem services and illuminate their values to humans in order to make environmental decisions easier and more effective. By creating *ad-hoc*, probabilistic models of both provision and usage of ES in a region of interest, ARIES helps discover, understand, and quantify environmental assets, their likely beneficiaries, and what factors influence their

Figure 1. A screenshot from the ARIES toolkit calculating the potential of an area to provide climate stability through carbon sequestration and storage.

value according to specified needs and priorities. In this contribution, we discuss the use of ARIES to understand how the consequences of agricultural decision-making may propagate along the causal chain of the broader spectrum of Ecosystem Services and illustrate perspectives for integration of ES thinking into agriculture.

Methods

Ecosystem services dynamics can be seen as a generalized source-sink problem, where ecosystems are the source of benefits that meet the needs of specific human beneficiaries. Modelling ES in a given spatial and temporal context requires: (1) determining the currencies of these benefits, such as water, CO_2 etc; (2) determining likely surfaces of both provision and usage relative to the area and time of interest; (3) quantifying the rates of flow of the correspondent benefits. It is the rate of flow (current or potential) that can be directly related to the value of the ES, both in abstract and in economic terms.

Most of the many difficulties of modelling ES depend on the high heterogeneity of behaviour exhibited by the benefits they produce. Among these:

1. Provision and usage happen at entirely independent scales in space and time. Therefore, a scale-explicit approach needs to be taken, and theoretical instruments that can tackle multi-scale systems are lacking.
2. The ‘currency’ of benefit provision is rarely an easily modelled biophysical quantity. Easier cases include, e.g., CO_2: quantification of its exchange from vegetation to atmosphere may be all that’s needed to assess benefits of carbon sequestration. Things are much more complex with currencies like sense of identity or avoided risk of flooding.
3. Little clarity exists in the literature about quantifiable definition of ES, their benefits, and the modalities of their propagation from ecosystem to human beneficiary.

The ARIES methodology is based on explicit conceptualizations (ontologies: Villa *et al*., 2009) that lay out first of all a novel vision of ES, based on the breakdown into individual benefits, each of which is modelled independently, then linked to the others. Domain ontologies in ARIES result from a large-scale expert consensus. Artificial intelligence techniques (machine reasoning, pattern recognition) examine source data and extract from the ontologies models that best represent the situation at hand. ARIES builds *ad-hoc*, probabilistic Bayesian Network models (Cowell *et al*., 1999) that inform the users of the full probability distribution of the outcomes of their decisions.

The result of an ARIES user session is an **environmental asset portfolio** that describes in depth the spatial distribution of benefits produced the area, their potential and realized values, and the causal relationships that link the values to each other, to their likely beneficiaries, and to actual or potential policies. Users can enter a scenario explorer module to explore the likely changes in Ecosystem Service (ES) provision and usage engendered by changed environmental conditions, consequent to either natural change or their own actions.

We will discuss the ARIES methodology and demonstrate the software toolkit to highlight its potential in informing ES-centric decision making in agriculture.

References

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