

# The ARIES Project

## ARTificial Intelligence for Ecosystem Services

### What it is

**ARIES** is a web-based technology offered to users worldwide to assist rapid ecosystem service assessment and valuation (ESAV). Its purpose is to make environmental decisions easier and more effective. ARIES helps discover, understand, and quantify environmental assets and what factors influence their values, in a geographical area and according to needs and priorities set by its users.

Created by the ARIES consortium, an international partnership of NGOs, policy-makers, and scientists, ARIES pairs the user's knowledge of a case study with that of experts, supported by a state-of-the-art database. Using a unique artificial intelligence approach, ARIES studies all the data relevant to ESAV questions and constructs a cause-and-effect picture of how ecological and economic factors interact in the selected area, making sure that not even a bit of relevant data or knowledge is overlooked. The result of an ARIES user session is an *environmental asset portfolio* that describes in depth the spatial distribution of ecosystems and ecosystem services in the area, their potential and realized economic values, likely trends for future values, and the causal relationships that link the values to each other and to actual or

potential policies. The directions and type of outcomes of an ARIES session are entirely decided by the user. The portfolio includes documentation and references that document and justify each and every operation, dataset, or model used to create it.

ARIES is the most recent in a series of federally funded projects aiming to provide intelligent support to ESAV; it started on April 1, 2007 thanks to a \$925,000 grant from the National Science Foundation to the UVM Ecoinformatics Collaboratory, Earth Economics, and Conservation International. Partners from Madagascar to Puget Sound are providing case studies, data and crucial knowledge to inform the ARIES algorithms. A fully functional portal will be available to the public at the end of the project in 2010, but demonstration, proof-of-concept and test releases will be made available starting in summer 2008.

ARIES is being developed following the open source software paradigm; unsupervised access to ARIES services will be open and free for all non-profit users, such as members of NGOs, academic, or governmental institutions. Non-profit users, in turn, commit to sharing data in modalities that best reflect their mission and commitments, contributing to the growth of the system over time. Access to ARIES for business

groups and professional support will also be made available through an independent organization, whose proceeds will support the maintenance and growth of the system.

This document provides a non-technical introduction to the principles underlying ARIES and previews some of the ways users will be able to interact with it. The ARIES web site (<http://ecoinformatics.uvm.edu/aries>) is the place to go to keep updated on project developments and to access tools and services created by our team on the road to ARIES.

## What users can do with ARIES

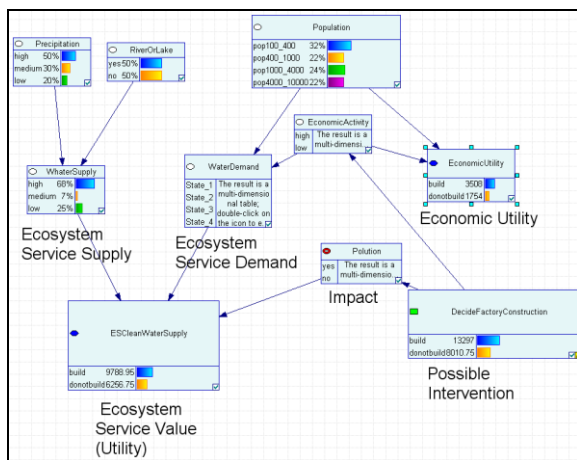
ARIES can accommodate a range of different use scenarios, including spatial assessments and economic valuations of ecosystem services, optimization of payment schemes for ecosystem services, and spatial policy planning. The table below provides examples of ARIES functionalities that match diverse user needs. Each user session of ARIES can contain one or more of the following functionalities depending on needs and priorities.

ARIES use	SAMPLE QUESTIONS ADDRESSED	SPATIAL SCALE
Spatial assessment and distribution of ecosystem services	What ecosystem services are being provided and where in space? Where are the beneficiaries of ES located in the landscape?	Local to National
Spatial economic valuation of ecosystem services	What is the economic value of the ES being provided, and how is this value distributed in space? What compensation amounts should be requested for a given environmental damage?	Local to National
Optimization of payment schemes for Ecosystem Services (PES)	Where is it best to invest in payment schemes for ES so as to optimize investment? What type of PES scheme is the most effective given the nature of the environmental assets? How are opportunity costs distributed in space? How are probabilities of land conversion distributed in space?	Watershed to Regional
Conservation planning	Where is it most efficient and cost-effective to invest in conservation for the combined provision of biodiversity and important ES?	Local, watershed, regional
Spatial policy planning	What policy tools (payments, penalties, property rights, persuasion and prescription) are likely to be most effective for the maintenance of ES and the minimization of environmental impact?	Local, watershed, regional
Forecasting of change in ES provision	How is land use change going to affect the provisioning and value of ES?	Local, watershed, regional

## How it works

ARIES purposely avoids predefined, “black box” models of how natural systems work, recognizing that management scenarios require specific knowledge defined by the users.

ARIES does not try to fit reality to a model that is known in advance. Rather, artificial intelligence is used to guide user input and turn it into an *ad-hoc* causal model of the situation under study. Step by step, the user is asked to approve any new causal relationships, environmental assets, or risk factors discovered by ARIES for insertion in the model.



The model built by ARIES is probabilistic, based on established technologies (Bayesian networks) that represent the state of the art in decision support systems. Probabilistic models are especially suited to deal with different levels of knowledge and uncertainty. All results of an ARIES session always carry an uncertainty estimate with them, which is made explicit to the user. Conditions of data scarcity may impose limits on the reliability of the results, but will not prevent results from being obtained. As new data become available, users

will be able to go back to their stored analysis and compute new results with improved confidence limits.

A typical ARIES usage scenario could include one or more of the following:

1. **Study definition.** The user enters information about the study area and the goals and policy objectives of the analysis.
2. **ES Districting and Baseline Portfolio creation.** ARIES consults its internal knowledge base and retrieves all known information about the study area in the desired policy scenario. On the basis of the information retrieved, it builds an initial portfolio of the potential environmental assets in the area and their relevance to the chosen policy scenario. A map of the asset distribution in space and an initial assessment of their relative values is then produced (Figure 1). The user can verify all information used to build the initial portfolio, and correct or exclude information as required, recalculating the baseline portfolio to satisfaction.
3. **Interview: Refinement of the portfolio.** ARIES reviews the baseline portfolio and uses an interview format to suggest the inclusion of additional knowledge. For example, proximity to certain land use types can trigger the inclusion of new assets or of risk factors that determine a change in the asset map. Users could also be invited to include data that will improve accuracy in establishing the potential for an ecosystem to deliver services, based on

the level of ecological integrity. This phase ends when all the relevant knowledge stored in the ARIES rule base has been considered and/or the user is satisfied with the outcome of the analysis.

4. **Economic valuation.** Users interested in an economic valuation of the environmental assets can ask ARIES to search for previously published economic data for the study area. In case in which data are not readily available, the system presents the user with the option of retrieving data from other comparable locations and gives information on ranges of transferability for each value. The latter is a measure of the confidence attributed by the system to the values for use in a different region. Upon agreement by the user, ARIES can build a map and summary statistics of economic value for the area.
5. **Priority analysis.** Different weights and priorities can be assigned in assessing and valuing natural assets. For example, the user can specify services and assets that are crucial to account for scarcity, demand, or different capacity of ecosystems to produce given services. The process can be reiterated

depending on preliminary portfolio results, as the system will discover new potential assets during the analysis. A multiple criteria model will assist the user in analyzing policy scenarios that take into account their crucial priorities.

6. **Scenario analysis.** In ARIES, geographic, socio-economic, and ecological knowledge for a case study is not simply compiled, but also structured and linked into probabilistic cause-and-effect models. Users interested in better understanding the effects of given changes in land use or policies on ecosystem services can perform scenario analysis based on the causal model by perturbing environmental or economic conditions and studying changes in the environmental assets portfolio.
7. **Reporting.** When the user is satisfied with the results of the ARIES session, reports of the outcomes can be generated, including download of spatial maps, statistics, and all public source information. According to the purpose of the analysis and the policy scenarios chosen, the reports may be of several different types (e.g. economic valuation, PES profile, general asset profile).

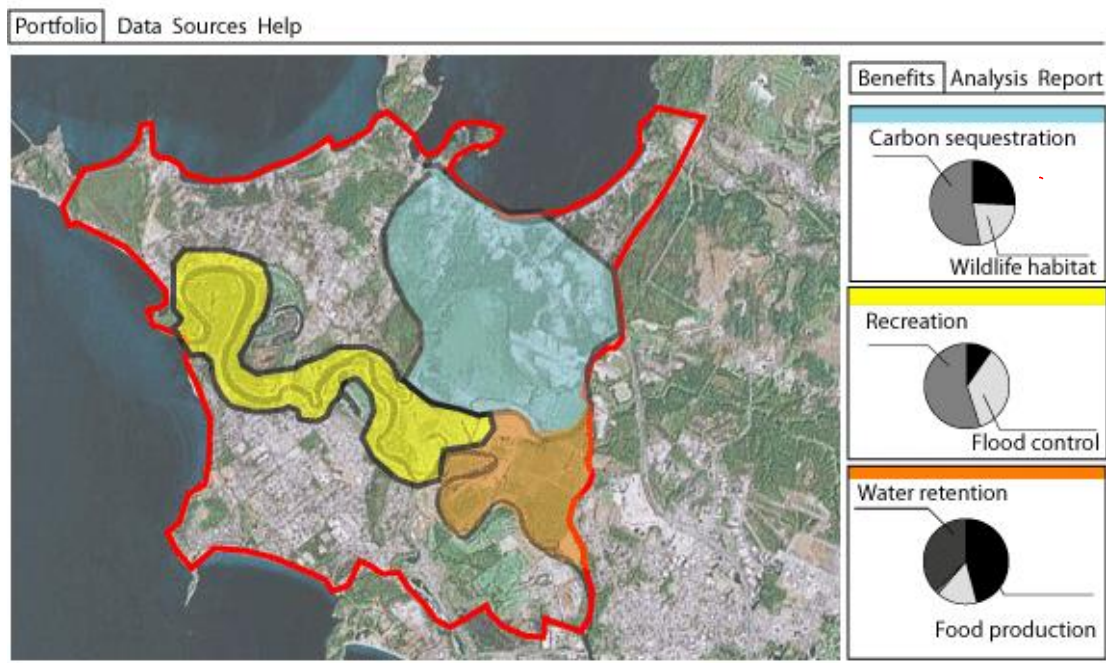


Figure 1. A preview of what the ARIES portfolio may look like at the end of a user’s session. The area chosen by the user (outlined in red) has been analyzed and automatically districted into areas providing distinct benefit configurations. For each configuration, represented by the different colors, the likely distribution of the ecosystem services associated with the discovered assets is summarized in the rightmost panel. The Analysis menu will detail all benefits discovered and their respective likelihoods with the available data. This initial benefit configuration is used as a starting point to interrogate the knowledge base and ask the user questions about possibly relevant factors. The menu choices on top of the panels provide access to the source information and all the data, criteria and uncertainties involved in the definition of the districts.

## How Artificial Intelligence works in ARIES

ARIES uses “intelligent” software agents to retrieve, analyze, and synthesize knowledge from various sources. Intelligent agents are more than conventional programs because they react to changing priorities and user choices and can use machine reasoning to modify the way they operate, thereby adapting to a case study as it develops. In order to allow this, all knowledge in ARIES is broken into its elemental concepts, each of which is defined and linked to other concepts to reflect the state-of-the-art understanding of ecological and socio-economic

phenomena. By transparently mapping the conceptualizations that underlie knowledge, ARIES builds a universal vocabulary (ontology) that allows the software to shape the user workflow to reflect needs and study areas and to correctly integrate diverse data from multiple sources. ARIES avoids the “black box” approach by emphasizing the user’s ability to track and modify each step of their assessment.

These properties allow for unprecedented discovery functions in ARIES. For example, environmental assets are discovered by analyzing the available layers of biophysical, land-use, ecological and socio-economic data

for the area, guided by the knowledge of what conditions make an environmental asset and its human beneficiaries likely to coexist in the temporal and spatial frame of the case study. The assets discovered are later classified into the ecosystem services that create them, so that the nature of the services is made explicit. For example, all the benefits linked to the service “soil retention” (e.g. reduced siltation of water reservoirs, preservation of near-shore coral reefs) are identified spatially in their likely area of relevance and mapped under a common heading for the service. All discovered assets are presented to the user for approval before becoming part of the portfolio. The result of this phase is a set of maps and summary data (e.g. Figure 1) reflecting the location and most likely distribution of environmental assets in a study area.

organizations to come together, unified by the urgent need to map, document, and value natural assets and ecosystem services in a wide range of natural and socio-economic contexts. Partnership in the ARIES consortium is a privileged way to directly collaborate with the ARIES team on case study development and documentation. Any interested party can become an ARIES Partner, based on mutual agreement on terms of knowledge sharing, and share the ownership of the ARIES service. Partnerships make ARIES stronger and more powerful, as they help evaluate, develop, and endorse transparent and reliable methodological protocols for ESV over increasingly broader scopes. Partnerships also help ensure continuity and provide high profile case studies. Current Partners include Conservation International, Earth Economics, and Wageningen University. Please contact [ecoinformatics@uvm.edu](mailto:ecoinformatics@uvm.edu) for more information about possible partnership arrangements.

## The ARIES consortium

ARIES is not just the development of an infrastructure, but also a reason for multiple

### Contact information



#### The ARIES consortium

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#### Conservation International

<http://www.conservation.org>



#### Earth Economics

<http://www.eartheconomics.org>