

**COST Foresight 2030
Benefiting from the Digital Revolution
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Natural Resources Management Workshop Report**

Natural Resources Management

A Great Whitewater Science Adventure

Ambre and Melanie had already donned their life jackets. They were a bit giddy after using the translation software newly installed in their “deviles” to flirt with those cute guys from Latvia. Ambre absentmindedly spun the end of her long blonde hair around her finger. Thierry could tell she wasn’t paying attention. “So, Ambre, when were the first restrictions on logging and grazing made in the Ubye Valley?”

Thierry wasn’t a teacher. Usually the company he founded with his wife Carla, Ubye Expeditions, ran ecotours for adults. The young couple got a healthy tax break and a handy marketing tool by adding a scientific component to their tours. They rode those two wheels like a Harley Davidson to prosperity. The translation software Thierry had forwarded overnight to the students’ mobile devices, which the kids insisted on calling “deviles,” was distributed free by the EU to all registered and approved ECRs – eco-citizen researchers, which the kids called “eekers.” Designed to allow often monolingual Eekers to transmit data to scientists all over the EU, the software would come in especially handy during this trip: among the 14 kids who would ride the rapids of the Ubye River, there was not a single common language.

Albeit distracted, Ambre had read the material. “There were restrictions put on logging and grazing in 1414,” she replied. Melanie opted for preemptive action: “And you could get fined for letting your goats graze in the forest before that, in 1337,” she chimed in without prompting.

Thierry was impressed. He recalled his best teacher. Also a nature enthusiast, his Dad once told him of a volunteer vacation to the Pantanal wetlands to collect scat and enter data into computer. The peons might have done better. Volunteer science tourism back then was to raise funds and awareness. Recent technological advances had changed everything.

Thierry told the students that sensors on the raft would collect data about discharge, water quality, pollution and fish populations – just to mention a few. Using just their deviles, they would record a series of supplemental observations in multimedia formats. Back in their labs, scientists will correlate this data with what they receive regularly from Sentinel 3 – a satellite of the EU Global Monitoring for Environment and Security (GMES) system.

When Thierry finally directed them towards the rafts, Melanie was so exhilarated at the prospect of being a whitewater scientist that Ambre had to

grab her by the wrist to hold her back. "Let's wait to make sure we get on the same boat as those Latvian guys," she said.

Introduction

Even in this era of unprecedented technological and scientific advance, nature repeatedly and ever more forcefully reminds humans that they live in a finite world with physical limits on the available resources. Information and Communication Technology (ICT) researchers may delve beyond silicon, add dimensions or experiment with spin waves and proteins to keep pace with Moore's Law¹, but at a human scale the era of limits has dawned.

Scientists can debate whether we have left the Holocene era for the Anthropocene, but most knowledgeable observers agree that human beings cannot sustain their current rate of consumption and that remedial action is needed to repair the damage already done to the earth. The time has come to place science and technology more fully at the service of sustainability and remedial ecology.

"We have gone beyond the idea that the planet will take care of itself," said Jacqueline M. McGlade, Executive Director of the European Environmental Agency (EEA). "We are in the era of managing the planet." Largely because of the effects of climate change on the deep seas, the era of management will probably last quite a while. "It will take many lifetimes to recover," she predicted.

The Natural Resources Management workshop of *COST Foresight 2030: Benefiting from the Digital Revolution*, brought together leading specialists in diverse areas ranging from forestry to oceanography, economics to information technology, and beyond. They were asked to brainstorm to identify emerging technologies and scientific developments in the field of ICT as it relates to natural resources management, identify mega-trends and their corresponding drivers, predict which technologies and related applications will be available by 2030, and recommend priorities for future research. Their contribution furthers the work of COST's Foresight 2030 series, the next round of which will address "societal organisation" in October 2009.

Where we are today – a legacy of unsustainable behaviour

The demand for natural resources continues to grow. The conventional model of economic development aims to maintain or even increase current levels of consumption for the well-to-do while gradually combating all aspects of poverty. As the population increases, more and more people are included. As different groups and individuals realise their great expectations, they come into conflict over the same resources: land that produces food is coveted by biomass energy investors; agricultural, industrial and residential customers squabble over water supplies; and ecotourists square off with dam builders and loggers in their efforts to maintain wild streams and pristine forests for recreational purposes. The personal interests of landowners may run contrary to the needs

¹ An empirical observation published in 1965 by Gordon E. Moore. He noted that since the invention of the integrated circuit in 1958, the number of transistors that can be placed inexpensively on an integrated circuit has increased exponentially, doubling approximately every two years.

of society. Efforts to take full advantage of opportunities in the short-term may clash with the interests of long-term sustainability.

Examples of unsustainable depletion of natural resources are abundant. Fully three-quarters of fisheries are over-exploited; at the current rate, the world will lose two-thirds of the species by the end of the century. Every year more than 32 billion cubic metres of drinking water are lost through leakage from distribution networks.

Some of this unsustainable use can be blamed in part on distorted markets and inadequate pricing models. European Union subsidies have contributed to over-fishing; argue two environmental NGOs, the Pew Environment Group and EU Transparency. “Tens of millions have been spent subsidising vessels and practices exacerbating illegal fishing, increasing EU fleet over-capacity, and compounding overfishing in European waters,” reported the UK newspaper *The Guardian* on June 25, 2009. Horst Korn, Head of the Biodiversity Unit of the German Federal Agency for Nature conservation, Germany, noted: “Not all subsidies are bad, but many are badly designed and favour interest groups. I think a lot of subsidies wouldn’t exist if people knew about them.”

At the same time, the externalisation of environmental costs means that society and third parties absorb liabilities that would more fairly be paid for by manufacturers and consumers. One classic example is historic soil contamination by industrial plants. On the flipside, owners of ecologically-valuable assets generally receive no compensation for responsible management. One of the biggest problems is that foresters are only paid for timber, not for drinking water – even though regulators demand that forest owners protect water resources. Some hope can be found in the frequent efforts to use the earth’s bounty in a more intelligent way. Many loggers in Europe and around the world are embracing forest certification and other sustainable models, for example.

A new model should be defined

Yet, these laudable efforts are likely to be insufficient, especially since ecosystems behave in ways that are often not linear. If they reach a certain threshold or tipping point, they are displaced from one state of equilibrium to another. Change becomes permanent and essentially irreversible.

The tipping point concept plays a major role in the climate change debate. Climate change will affect and, in turn, be affected by natural resources management. Humans have altered deeply the natural functioning of the planet, agreed participants. The ancient approach was carbon neutral, but more recently human activity has pushed that relationship out of balance. Participants suggested that humans should define a new model where there is a balance between the natural resources and human use of them.

Natural Resources Management Vision 2030

The workshop was designed to look specifically at Europe and its future; however, participants agreed that the continent must be considered in relationship to the rest of the world. Europe must pay attention to its ecological footprint abroad and refrain from exporting its problems. It would be irresponsible to “manage our own forests in a sustainably but import unsustainably harvested timber,” commented Korn.

Workshop participants focused on concepts that they believe should guide the way society manages natural resources, particularly in the context of global environmental changes. For starters, humans should aim to allow no further erosion of the planet’s natural capital and the ecosystem services, meaning food, feed, fibres, fuel, pharmaceuticals, water resources, etc. Participants also agreed that humans must reduce as much as possible the volume and toxicity of waste and in particular to ban the release of substances that cannot be detoxified by natural processes.

In the case of fresh water, the above-mentioned goals dovetail to a large extent with the Water Framework Directive (WFD), described by the U-K Department for Environment, Food and Rural Affairs (DEFRA) as “as the most substantial piece of EC water legislation to date.” The WFD is “designed to improve and integrate the way water bodies are managed throughout Europe ... Member States must aim to reach good chemical and ecological status in inland and coastal waters by 2015. It is designed to: enhance the status and prevent further deterioration of aquatic ecosystems and associated wetlands, which depend on the aquatic ecosystems; promote the sustainable use of water; reduce pollution of water, especially by ‘priority’ and ‘priority hazardous’ substances; (and) ensure progressive reduction of groundwater pollution.”

Future technologies, applications and other measures

Participants defined several tools that would apply across-the-board and also focused on three specific areas:

- Monitoring.
- Data management and knowledge management.
- Improvement of decision-making support systems.

With two dozen official languages and more than twice that number of unofficial “minority” tongues, the European Union has gathered a modern day Babel under its umbrella. Scientists, policymakers and other elites can communicate in a handful of major languages, notably English. However, if regular people are truly going to be engaged in gathering data and using information and knowledge, collection and dissemination must be performed in a wide variety of languages.

The question of language is important, especially if the idea is to involve local communities, agreed participants. Just one example of the type of technology that could become available in 20 years: in the United States, an electronic gadget for simultaneous translation is envisioned as part of infantry equipment in the Pentagon’s Future Soldier 2030 programme.

Other overarching goals include safe data storage and greater compatibility of data systems. Information and Communication Technologies (ICT) and Computer and Communication Sciences and Technologies (CCST) should contribute to the sustainable management of natural resources by developing a system of monitoring of ecosystems and natural resources in real time, by providing access to high-quality controlled databases using remote sensing techniques and geographical information systems, agreed participants.

Crowd sourcing research, whereby regular citizens help collect data, proved to be a consensus favourite among workshop participants. Traditional data has been “formal” – collected in a very designed way. Crowd sourcing allows for a greater quantity of information. Each piece might be less well defined, but statistics can be applied to garner knowledge. By 2030 networks that are all pervasive could be available if humans match sensors in a novel way. Some of the data collected will be unreliable, but the amount increases exponentially so scientists can use statistics to glean useful data. Already soil scientists are using data from samples sent to laboratories by individual farmers for their own purposes. In the past researchers had but one choice: to trudge into the field to collect clumps of dirt themselves. In addition to providing data, citizens can contribute computing power from their PCs to a network that researchers can use for processing when heavy lifting is in order. Called pooling, this kind of system is already being used for climate modelling.

Finally, participants offered a suggestion that might seem mundane in terms of new technology, but which could have a potentially huge impact – to make better use of already available data and systems. The Global Earth Observation System of Systems (GEOSS) was cited as an example. As the GEOSS website explains, “This ‘system of systems’ will proactively link together existing and planned observing systems around the world and support the development of new systems where gaps currently exist.”

Monitoring

“The first step is the collection of data,” said Allan Watt, Deputy Head of the Biodiversity Research Programme at the Centre for Ecology and Hydrology in the United Kingdom. “We need to collect data more efficiently on what is relatively easy and also obtain more information about biodiversity. That is really challenging, and ICT is important.”

One relatively simple step toward improved data collection would be to make better and cheaper sensors more widely available. Various space and airborne sensors, field scanning methods, and automatic measuring systems need to be developed further for accurate and economic data collection, participants agreed. Today, most sensors are made in the United States, but as Europe invests more heavily in programmes that make use of them, manufacturers might consider developing this sector.

More sophisticated and complex sensors could provide an array of data not currently available. Participants encouraged scientists to do some lateral

thinking about new kinds of sensors that might include webcams, environmental audio (for example, to calculate species density), and tree-growth sensors. Some suggested that radio frequency identification (RFID) might be used not only in research for tracking animals in nature but also for tracking food products and timber from point of origin to market so that consumers can know that they are buying responsibly cultivated, harvested or caught products.

Participants called attention to something already available called smart dust sensors. These tiny wireless microelectromechanical systems (MEMS) can detect everything from light to vibrations. The size of a pea or a grain of rice, they sleep 99% of the time but wake up to take a measurement at a certain frequency, for example, every 10 minutes. Once a day they send the results to a neighbour. Through a mesh network the data are sent to a parent that gathers smart elements. Smart dust sensors can be used for activities such as checking the structural safety of buildings after an earthquake. Participants also expressed enthusiasm for the development of another kind of MEMS device, a chemical lab-on-a-chip that could be placed in the environment.

Sensors can be distributed to citizens to take advantage of crowd sourcing techniques. An article in the 4 June 2009 edition of *The Economist* highlighted the work of Eric Paulos, a computer scientist at Carnegie Mellon University in the United States, who has distributed sensors to street sweepers in San Francisco, California, and taxis in Accra, the capital of Ghana, to measure pollution levels. Graduate students at Carnegie Mellon's Living Environments Lab gave homeowners sensors to sample tap water and indoor-air quality.

Participants agreed that technologies should be developed to allow citizens to participate more broadly in data collection. This might be a more sophisticated version of something already developed by Nokia – a prototype of a mobile handset that, according to the manufacturer, “can sense and analyse your environment, health, and local weather conditions.” Interactive technologies could provide feedback to improve the quality and experience of citizen engagement, participants suggested.

Special tools could be developed to monitor the demand for natural resources. The demand for wood and natural resources is constantly increasing, and loggers need to know which forests areas are not available for exploitation. For that, they need better information and visualisation. Some participants proposed that “no harvest” and “no take zones” should be better marked and controlled. Electronic devices which may switch off machinery when crossing the border would help in preserving these resources.

Managing data and knowledge

“Data management might seem boring, it means talking about semantics, but we need it,” said Watt. “It is really exciting to see what can be done to collect, organise and disseminate data in interesting ways.” Participants agreed that data are not always managed in efficiently. Yet, without proper data management, policymakers will not have the right information at the right time.

In a plenary presentation, Gian Mario Maggio, Senior Science Officer with COST, noted that each day hundreds of billions of data points are collected from sensors around the globe that are monitoring things such as pollution levels. This huge amount of information – available as text, objects, images, videos, multimedia, etc. – poses new management challenges in the realms of storage, aggregation, searching, filtering, trusting and certification. Technology is needed to “automatically” enrich information with semantics but also to supply cooperative tools for aggregation, organisation, and augmentation. Workshop participants also stressed the need for automated pre-treatment of data.

Semantic annotation is in its infancy, Maggio noted. Significant results can be achieved through deep analysis only in specialised domains; generally, today, applicable methods allow only for shallow analysis. Deep analysis with inference will eventually complement and merge with simulation to lead to unprecedented predictive power, Maggio predicted. Semantics representation still lacks adequate formal and logical representation, and there remains a need for languages, methods and tools for producing high quality software, he added.

Workshop participants pointed to the desirability of tools to ensure better traceability and quality control of data. They also called for better multilayered databases (MLDB) linked with geographic information systems (GIS) applications and improved precision management tools that link maps to other data. They also agreed that systems should be developed to ensure better checking and interpretation of data.

Improving decision-making support systems

To make better informed decisions, support systems need to be improved. In particular, their predictive power – based on even incomplete data sets – should be increased. Better modelling, including better mathematics, proved to be a recurring theme during the workshop, as did better analytical and visualisation tools. Participants predicted a significant increase in modelling capabilities.

“Self-sustainable” individuals

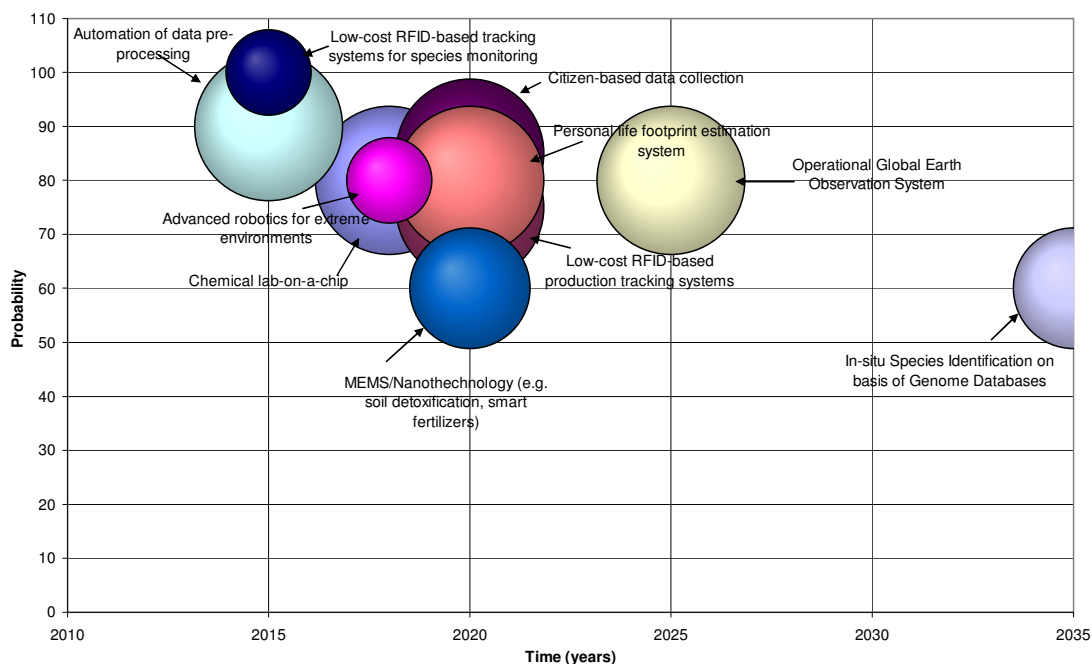
In his plenary presentation, *Harnessing the Digital Revolution*, Maggio included examples from the environmental and resources management arena. In the future, individuals may become more “self-sustainable,” as he put it. New technologies will help people adapt their lifestyles and make them more ecologically friendly. A new societal actor known as a “prosumer” (a contraction of producer and consumer) will be able to independently generate and store energy, for example. Instead of today’s poorly estimated CO₂ footprint, individuals will have Individual Life Footprints to help guide them toward responsible and sustainable actions.

Roadmap 2030

Participants agreed on a technology roadmap leading up to 2030. Automated data processing and low-cost RFID-based tracking systems for species monitoring were both expected to almost certainly come online by 2015.

A chemical lab-on-chip and advanced robotics for extreme environments are almost nearly certain to be available by before 2020, they predicted. Citizen-based data collection and personalised environmental footprints are very likely to be available by about 10 years from now.

There is about a 60% chance that MEMS/Nanotechnology will be available for applications like soil detoxification and smart fertilisers around the same time. By 2025, there's an 80% chance that global earth observation systems will be operational. Finally, a bit beyond 2030, by 2035, there's more than a 50% chance that genome databases will be used for on site species identification.



Challenges ahead

To be managed in a sustainable way, natural resources must be balanced on various axes to reflect the characteristics of the resources and the multiple and conflicting demands placed on them, agreed participants. Other factors that deserve consideration are the effects of climate change, time (long-term vs. short-term) and space (for example, thinking on the landscape level).

Complex mathematical models will be needed to link the sundry variables, such as water regime, soil types, tree species and extreme events. At the same time, the often differing interests of various groups in society must be taken into consideration, with costs and benefits parcelled out fairly.

Workshop participants also noted that natural resources should be managed in a way that will allow and encourage adaptation to global change, notably to climate change and the extreme events that are becoming more common as a result. This conclusion is in keeping with the results of an April 2009 European

Commission White Paper that presented a framework within which the EU and its Member States can prepare for the impacts of climate change.

When the report was issued, European Commissioner for the Environment Stavros Dimas said: "The seriousness of climate change is becoming greater and more disturbing with each passing year. We must work hard to reduce carbon emissions, but even with the emission reductions we are committed to achieving, some amount of climate change is inevitable. It is therefore essential that we start work now with governments, business, and communities to develop a comprehensive adaptation strategy for the EU and to ensure that adaptation is integrated into key EU policies."

Two specific actions were cited during the workshop:

- The establishment and/or extension of ecological corridors that allow species to migrate in response to a changing environment
- The recovery of fisheries that are affected by climate changes.

New economic indicators must be developed to more fully and accurately reflect the costs and benefits of a healthy (or sick) environment and ecosystem services, participants noted. Critics argue that the gross domestic product (GDP) represents merely a cash flow model. It ignores environmental and human assets from aquifers to housework. Indeed, expenses incurred to counter environmental damage increase GDP.

Participants called for the development of models based on the objectives of the economic activities. They also stressed the need to calculate environmental externalities both in terms of money and in non-monetary ways.

Adaptive management, using rapid, sometimes near real-time, feedback mechanisms, was considered key. Another major challenge, especially given the explosion in available data, would be to locate relevant information sources that correspond to any particular situation or problem.

Participants also expressed concern about the intellectual property rights (IPR) of data and suggested that perhaps a system of rewards or recognition be created for data providers. This is important not only because scientists will be using greater amounts of crowd sourced data collected by independents and stored in large institutional data banks but also because many private interests are hoarding what could be extremely useful data.

Data providers need to be given rewards so they won't sit on the data, agreed participants. As an example Didier Babin, Researcher, CIRAD Montpellier, France, added: "Veolia [the French water company] is perhaps the most important follower of data on rivers in the world."

Drivers of Success

Participants did not discuss this topic in sufficient depth.

Recommendations for ICT applications

The workshop split its recommendations into two groups: technical and general.

Technical recommendations

Participants agreed that new and better sensors should be developed to allow for faster, cheaper, more robust and customised monitoring and that smart dust sensor research should be part of this effort. They suggested that tracking systems should be improved and that RFID technology should be developed for this purpose.

In addition, robotics should be developed for submerged and submarine applications. Data collection and data management should be improved, something that would include the development of more diversified data sources.

Quality assurance systems should be developed for data analysis, participants agreed. Finally, they believed that devices should be developed to enable citizen-based data collection, for example through the use of more sophisticated mobile phones or other devices.

General recommendations

Participants stressed that systems should be developed to guarantee the development of and access to diversified sources of information. They backed the idea of creating decision-making support systems, such as computer modelling, which can integrate data from different disciplines.

Participants agreed that improvements should be made in the automation and control of processes. In terms of access to information, they noted that everyone should enjoy guaranteed access. Finally, participants suggested that foresight studies should be developed by sector to identify in more detail the technological needs and potential in each specific area.