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Activity Report 2018

Project-Team STEEP

Sustainability transition, environment, economy and local policy

IN COLLABORATION WITH: Laboratoire Jean Kuntzmann (LJK)

RESEARCH CENTER
Grenoble - Rhône-Alpes

THEME
Earth, Environmental and Energy Sciences

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Project-Team STEEP

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A6.1. - Methods in mathematical modeling
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B8.5.1. - Participative democracy
B8.5.3. - Collaborative economy
B9.9. - Ethics

1. Team, Visitors, External Collaborators

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2. Overall Objectives

2.1. Overview

STEEP started in January 2010, initially as an Inria "Action Exploratoire" (2010+2011). It is now an "Équipe Projet Inria" of Inria Grenoble - Rhône-Alpes and is also affiliated with the Jean Kuntzmann laboratory (LJK [1]).

STEEP is an interdisciplinary research team devoted to systemic modelling and simulation of the interactions between the environmental, economic and social factors in the context of a transition to sustainability at local (sub-national) scales. Our goal is to develop decision-making tools to support decision makers in the implementation of this transition by developing simulation and optimization programs. In other words, our objective is to set up some mathematical and computational tools which enable us to provide some parts of the answer to the challenges *how to operate the sustainable development at local scales? and which local governance for environmental public policies?*.

The work of STEEP follows several research directions, covering different application domains; these are described in "Scientific Foundations" and "Application Domains" respectively.

2.2. Sustainable development: issues and research opportunities

Environmental issues now pose a threat to human civilization worldwide. They range from falling water tables to eroding soils, expanding deserts, biodiversity loss, rising temperatures, *etc*. For example, half the world's population lives in countries where water tables are falling as aquifers are being depleted. Roughly a third of the world's cropland is losing topsoil at an excessive rate. Glaciers are melting in all of the world's major mountains. The consequences on the present human societies are critical; they comprise for example a decreasing food security, important population movements (such as climate refugees) and explosive geopolitical tensions.

Sustainable development is often formulated in terms of a required balance between its environmental, economic and social dimensions, but in practice public policies addressing sustainability issues are dominantly oriented towards environment management in Western countries. This approach is problematic to some extent as environmental problems and sustainability issues result from socio-economic phenomena (for example the economic growth model which is strengthened by powerful and polluting technologies). Environmental problems have only recently been the object of media attention and public awareness. Most efforts bear on developing technological solutions. However, it is now clear that this will not be sufficient. We need to rethink our socio-economic and institutional models in order to leave room for a possible paradigm shift. In this perspective, we believe that crucial steps should be taken in research to help elaborating and implementing socio-economic alternatives.

The risks associated with delayed reaction and adaptation times make the situation urgent. Delayed reactions significantly increase the probability of overshoot of the planet carrying capacity followed by uncontrolled and irreversible evolution on a number of fronts . This systemic problem is amplified by two facts: the environment is degrading on all fronts at the same time, and at the global planetary scale, a first in human history.

Although environmental challenges are monitored worldwide, the search for appropriate lines of actions must nevertheless take place at all institutional levels, in particular at local scales.At such scales, the proximity and smaller number of stakeholders allows decision makers to reach a consensus much more easily than at national or international scales. The failure of the recent Copenhagen summit (and for that matter of all climate summits since the adoption of the Kyoto protocol in 1997) is a good illustration of the difficulties encountered in international negotiations. There are significant possibilities for operations at local scales, and the emergency of the situation gives the "think locally to act globally" logic an essential opportunity.

[1] http://ljk.imag.fr/

As of now, local decision levels have real political and economic leverage, and are more and more proactive on sustainability issues, either independently or in coordination through nationwide or European networks (we can refer for example to the European GMO-free Regions Network [2] or to the Network of European Regions for a Competitive and Sustainable TouRism [3]). Also, we think that two local scales are going to be increasingly dominant in the near future: urban areas (more exactly the employment areas of main cities) and "regions" (such as régions in France, Lander in Germany or Cantons in Switzerland). In particular, the sustainability of urban areas is one of the key issues of this century. As focal points of human activity, urban areas concentrate and amplify environmental pressures in a direct or indirect way.

Urbanization is a global and an ever-increasing trend process, with more than half the human population living in cities. Although urbanized areas still represent a very small fraction of the total terrestrial surface, urban resource consumption amounts to three-fourths of the annual total in energy, water, building materials, agricultural products etc., and pollution and waste management is a growing concern for urban planners worldwide. In France, for example, even if resource intensity (materials use divided by GDP [4]) has been reduced by half since the 70s, the actual material use (total and per inhabitant) has remained essentially constant, and household wastes have grown by 20% since 1995. Greenhouse gas (GHG) emissions have been reduced by a few percent since 1990, but the transportation share (a major issue on this front) has been steadily growing over the same period.

Furthermore, urban sprawl is a ubiquitous phenomenon showing no sign of slackening yet, even in countries where rural depopulation has long been stabilized. Urban sprawl in industrialized countries is largely driven by residential suburban growth. This phenomenon has both social and environmental consequences. First it implies an increase of daily mobility. In a context of high dependency on private cars and uncertainty on energy prices, this translates into an increased vulnerability of some population categories. It also induces an increase in greenhouse gas emissions, as well as an irreversible loss of cropland and a fragmentation of ecological habitat, with negative effects on biodiversity. The increasing concerns about climate change and upheaval in the market price of fossil fuels raise many questions about urban energy consumption while reviving the debate on the desirable urban structures and their determinants. Controlling urban sprawl is therefore a key sustainability issue.

Let us mention here that cities cannot be sustainable by themselves and that from this point of view, it does not make sense to focus on the municipality scale ("*communes*"). We think that it is very important to work at larger scales, typically, at employment catchment areas complemented by the adjacent agricultural and natural zones they are dependent on (that would correspond to the smallest scale for which a systemic analysis could make sense). Nevertheless, let us emphasize that because of resource imports and waste exports (e.g. GHG emissions), for any limited territory, the considered area will always depend on and impact other more or less distant territories. This is one of the key issues when trying to assess local sustainability.

Finally, let us note that the numerous and interrelated pressures exerted by human activities on the environment make the identification of sustainable development pathways arduous in a context of complex and sometimes conflicting stakeholders and socio-ecological interactions. This is why we also think that it is crucial to develop interdisciplinary and integrated approaches; consequently, our proposal tries to address the entire spectrum from scientific expertise to stakeholder decision-help.

STEEP, with its strong background in various areas of applied mathematics and modeling, can be a game changer in three connected key domains: urban economy, and related transportation and land use issues; material flow analysis and ecological accounting; and ecosystem services modeling. The group potential on these fronts relies on its capabilities to strongly improve existing integrated activity / land use / transportation models at the urban level on the one hand, and on the other, to build new and comprehensive decision-help tools for sustainability policies at the local and regional levels, in particular through the analysis of strategic social–environmental trade-offs between various policy options.

[2] http://www.gmo-free-regions.org

[3] http://www.necstour.eu

[4] Gross Domestic Product (GDP) is defined as an aggregate measure of production equal to the sum of the gross values added of all resident institutional units engaged in production.

3. Research Program

3.1. Development of numerical systemic models (economy / society /environment) at local scales

The problem we consider is intrinsically interdisciplinary: it draws on social sciences, ecology or science of the planet. The modeling of the considered phenomena must take into account many factors of different nature which interact with varied functional relationships. These heterogeneous dynamics are *a priori* nonlinear and complex: they may have saturation mechanisms, threshold effects, and may be density dependent. The difficulties are compounded by the strong interconnections of the system (presence of important feedback loops) and multi-scale spatial interactions. Environmental and social phenomena are indeed constrained by the geometry of the area in which they occur. Climate and urbanization are typical examples. These spatial processes involve proximity relationships and neighborhoods, like for example, between two adjacent parcels of land, or between several macroscopic levels of a social organization. The multi-scale issues are due to the simultaneous consideration in the modeling of actors of different types and that operate at specific scales (spatial and temporal). For example, to properly address biodiversity issues, the scale at which we must consider the evolution of rurality is probably very different from the one at which we model the biological phenomena.

In this context, to develop flexible integrated systemic models (upgradable, modular, ...) which are efficient, realistic and easy to use (for developers, modelers and end users) is a challenge in itself. What mathematical representations and what computational tools to use? Nowadays many tools are used: for example, cellular automata (e.g. in the LEAM model), agent models (e.g. URBANSIM [5]), system dynamics (e.g. World3), large systems of ordinary equations (e.g. equilibrium models such as TRANUS), and so on. Each of these tools has strengths and weaknesses. Is it necessary to invent other representations? What is the relevant level of modularity? How to get very modular models while keeping them very coherent and easy to calibrate? Is it preferable to use the same modeling tools for the whole system, or can we freely change the representation for each considered subsystem? How to easily and effectively manage different scales? (difficulty appearing in particular during the calibration process). How to get models which automatically adapt to the granularity of the data and which are always numerically stable? (this has also a direct link with the calibration processes and the propagation of uncertainties). How to develop models that can be calibrated with reasonable efforts, consistent with the (human and material) resources of the agencies and consulting firms that use them?

Before describing our research axes, we provide a brief overview of the types of models that we are or will be working with. As for LUTI (Land Use and Transportation Integrated) modeling, we have been using the TRANUS model since the start of our group. It is the most widely used LUTI model, has been developed since 1982 by the company Modelistica, and is distributed *via* Open Source software. TRANUS proceeds by solving a system of deterministic nonlinear equations and inequalities containing a number of economic parameters (e.g. demand elasticity parameters, location dispersion parameters, etc.). The solution of such a system represents an economic equilibrium between supply and demand.

On the other hand, the scientific domains related to ecosystem services and ecological accounting are much less mature than the one of urban economy from a modelling point of view (as a consequence of our more limited knowledge of the relevant complex processes and/or more limited available data). Nowadays, the community working on ecological accounting develops statistical models based on the enforcement of the mass conservation constraint for accounting for material fluxes through a territorial unit or a supply chain, relying on more or less simple data correlations when the relevant data is missing; the overall modelling makes heavy use of more or less sophisticated linear algebra and constrained optimization techniques. The ecosystem service community has been using statical models too, but is also developing more sophisticated models based for example on system dynamics, multi-agent type simulations or cellular models. In the ESNET project, STEEP has worked in particular on a land use/ land cover change (LUCC) modelling environments (Dinamica [6]) which belongs to the category of spatially explicit statistical models.

[5] http://www.urbansim.org

In the following, our two main research axes are described, from the point of view of applied mathematical development. The domains of application of this research effort is described in the application section, where some details about the context of each field is given.

3.2. Model calibration and validation

The overall calibration of the parameters that drive the equations implemented in the above models is a vital step. Theoretically, as the implemented equations describe e.g. socio-economic phenomena, some of these parameters should in principle be accurately estimated from past data using econometrics and statistical methods like regressions or maximum likelihood estimates, e.g. for the parameters of logit models describing the residential choices of households. However, this theoretical consideration is often not efficient in practice for at least two main reasons. First, the above models consist of several interacting modules. Currently, these modules are typically calibrated independently; this is clearly sub-optimal as results will differ from those obtained after a global calibration of the interaction system, which is the actual final objective of a calibration procedure. Second, the lack of data is an inherent problem.

As a consequence, models are usually calibrated by hand. The calibration can typically take up to 6 months for a medium size LUTI model (about 100 geographic zones, about 10 sectors including economic sectors, population and employment categories). This clearly emphasizes the need to further investigate and at least semi-automate the calibration process. Yet, in all domains STEEP considers, very few studies have addressed this central issue, not to mention calibration under uncertainty which has largely been ignored (with the exception of a few uncertainty propagation analyses reported in the literature).

Besides uncertainty analysis, another main aspect of calibration is numerical optimization. The general state-of-the-art on optimization procedures is extremely large and mature, covering many different types of optimization problems, in terms of size (number of parameters and data) and type of cost function(s) and constraints. Depending on the characteristics of the considered models in terms of dimension, data availability and quality, deterministic or stochastic methods will be implemented. For the former, due to the presence of non-differentiability, it is likely, depending on their severity, that derivative free control methods will have to be preferred. For the latter, particle-based filtering techniques and/or metamodel-based optimization techniques (also called response surfaces or surrogate models) are good candidates.

These methods will be validated, by performing a series of tests to verify that the optimization algorithms are efficient in the sense that 1) they converge after an acceptable computing time, 2) they are robust and 3) that the algorithms do what they are actually meant to. For the latter, the procedure for this algorithmic validation phase will be to measure the quality of the results obtained after the calibration, i.e. we have to analyze if the calibrated model fits sufficiently well the data according to predetermined criteria.

To summarize, the overall goal of this research axis is to address two major issues related to calibration and validation of models: (a) defining a calibration methodology and developing relevant and efficient algorithms to facilitate the parameter estimation of considered models; (b) defining a validation methodology and developing the related algorithms (this is complemented by sensitivity analysis, see the following section). In both cases, analyzing the uncertainty that may arise either from the data or the underlying equations, and quantifying how these uncertainties propagate in the model, are of major importance. We will work on all those issues for the models of all the applied domains covered by STEEP.

3.3. Sensitivity analysis

A sensitivity analysis (SA) consists, in a nutshell, in studying how the uncertainty in the output of a model can be apportioned to different sources of uncertainty in the model inputs. It is complementary to an uncertainty analysis, which focuses on quantifying uncertainty in model output. SA's can be useful for several purposes, such as guiding model development and identifying the most influential model parameters and critical data items. Identifying influential model parameters may help in divising metamodels (or, surrogate models) that approximate an original model and may be simulated, calibrated, or analyzed more efficiently. As for detecting

[6] http://www.csr.ufmg.br/dinamica/

critical data items, this may indicate for which type of data more effort must be spent in the data collection process in order to eventually improve the model's reliability. Finally, SA can be used as one means for validating models, together with validation based on historical data (or, put simply, using training and test data) and validation of model parameters and outputs by experts in the respective application area.

The first two applications of SA are linked to model calibration, discussed in the previous section. Indeed, prior to the development of the calibration tools, one important step is to select the significant or sensitive parameters and to evaluate the robustness of the calibration results with respect to data noise (stability studies). This may be performed through a global sensitivity analysis, e.g. by computation of Sobol's indices. Many problems had been to be circumvented e.g. difficulties arising from dependencies of input variables, variables that obey a spatial organization, or switch inputs. We take up on current work in the statistics community on SA for these difficult cases.

As for the third application of SA, model validation, a preliminary task bears on the propagation of uncertainties. Identifying the sources of uncertainties and their nature is crucial to propagate them via Monte Carlo techniques. To make a Monte Carlo approach computationally feasible, it is necessary to develop specific metamodels. Both the identification of the uncertainties and their propagation require a detailed knowledge of the data collection process; these are mandatory steps before a validation procedure based on SA can be implemented. First, we focus on validating LUTI models, starting with the CITiES ANR project: here, an SA consists in defining various land use policies and transportation scenarios and in using these scenarios to test the integrated land use and transportation model. Current approaches for validation by SA consider several scenarios and propose various indicators to measure the simulated changes. We work towards using sensitivity indices based on functional analysis of variance, which allow us to compare the influence of various inputs on the indicators. For example it allow the comparison of the influences of transportation and land use policies on several indicators.

4. Highlights of the Year

4.1. Highlights of the Year

The STEEP research team has initiated in 2016 a series of conferences-debates entitled "Understanding & Acting" (« Comprendre et agir ») that examines sustainability issues in order to help researchers and citizens to increase their awareness of the various issues at stake in order to initiate relevant individual and collective actions. The presentations are captured on video and then made directly accessible on the YouTube Channel "Comprendre et Agir". At the end of 2018 the YouTube channel reached more than **150,000 views with a rate of integral viewings remaining at above 25%.** This rate is quite important since the YouTube videos of the conferences last between 35 and 45 minutes. Our Youtube channel now has more than 2000 subscribers.

5. New Software and Platforms

5.1. Software tools for the TRANUS LUTI Model

KEYWORDS: Urban planning - Transport model - LUTI
FUNCTIONAL DESCRIPTION: This year, we have consolidated and extended our software tools for the TRANUS LUTI model, thanks to support by Inria allowing to hire an engineer for one year Emna Jribi (ADT TRACAV project). Various tasks have been accomplished, concerning three types of functionality, these are as follows. First, calibration of TRANUS. The software implementation of our methods for calibrating the TRANUS land-use component has been cleaned up. It has been encapsulated such as to be seamlessly integrated within the TRANUS workflow (consisting of a sequence of executables, exchanging data through binary and other files). Second, graphical user interfaces to facilitate the repeated execution of TRANUS executables, for generating reports on results or for the exploration of the space of some critical model parameters. Third, we have continued to work on the embedding of TRANUS within the open source QGIS platform (a widely used Geographic Information System).

- Participants: Emna Jribi, Thomas Capelle and Peter Sturm
- Contact: Peter Sturm
- URL: https://gitlab.inria.fr/tranus

5.2. USAT

Urban Sprawl Analysis Toolkit
KEYWORDS: Urban sprawl - Urban planning
FUNCTIONAL DESCRIPTION: This software allows to calculate and analyse indices of urban sprawl from open data (OpenStreetMap), aimed to be used by urban scientists and urban planners. A spatialized version of indices measuring the accessibility, dispersion and land use mix is calculated. The implemented methods are described in [9].

- Participants: Luciano Gervasoni, Serge Fenet and Peter Sturm
- Partner: LIRIS
- Contact: Peter Sturm
- URL: https://github.com/lgervasoni/urbansprawl

5.3. USAT WEB

Urban Sprawl Analysis Toolkit Web-service
KEYWORDS: Urban planning - Urban sprawl
FUNCTIONAL DESCRIPTION: This is a web-service on top of the software USAT described above. The web-service will allow any user to select a region of interest and to launch the calculation and display of sprawl indices using USAT. It is in the process of being hosted on the HPC platform of IN2P3, after which it will be made open to the public. The source code for this web-service is already available at the below site.

The web-service is described in [10].

- Participants: Lucas Rezakhanlou, Peter Sturm, Luciano Gervasoni and Serge Fenet
- Contact: Peter Sturm
- Publication: USAT (Urban Sprawl Analysis Toolkit) : une plateforme web d'analyse de l'étalement urbain à partir de données massives ouvertes
- URL: https://gitlab.inria.fr/lrezakha/usat-web

5.4. InterfacesTRANUS

FUNCTIONAL DESCRIPTION: This software contains two interfaces dedicated to facilitating the usage of the TRANUS integrated land use and transport model+software. The first interface is dedicated to enabling the execution of the TRANUS binary programs without the need to use the console or the TRANUS GUI. The second interface provides an aid for calibrating a TRANUS model, by interactively exploring ranges of different parameters of a TRANUS model and visualising model outputs across these ranges.

- Participants: Julien Armand, Peter Sturm and Thomas Capelle
- Contact: Peter Sturm
- URL: https://gitlab.inria.fr/tranus/TRANUS_Interfaces

5.5. LUM_OSM

Land Use Mix calculation from OpenStreepMap data

FUNCTIONAL DESCRIPTION: The software uses Mapzen Metro Extracts to retrieve the OpenStreetMap data of a given region in the PostgreSQL format. Afterwards, a continuous representation of residential and activity land uses is created. Finally, a GIS output containing the degree of land use mixture is calculated by means of using the land uses maps. The implemented approach is documented in the paper "A framework for evaluating urban land use mix from crowd-sourcing data", http://hal.inria.fr/hal-01396792

- Participants: Luciano Gervasoni, Marti Bosch Padros, Peter Sturm and Serge Fenet
- Partners: EPFL - Ecole Polytechnique Fédérale de Lausanne - LIRIS
- Contact: Peter Sturm
- URL: http://github.com/martibosch/landusemix

5.6. QGIS_Tranus_Reports

FUNCTIONAL DESCRIPTION: This software allows to graphically visualise data output by the TRANUS LUTI model (and possibly, of any other data of the same structure). In particular, this concerns any data items defined per zone of a modelled territory (productions, indicators, etc.). The software is designed as a plugin for the geographical information system platform QGIS and can be run interactively as well as by the command line or by a call from within another software. The interactive mode (within QGIS) allows the user to define graphical outputs to be generated from TRANUS output files (type of graphs to be generated – 2D or 3D – color coding to be used, choice of data to be displayed, etc.). Visualisation of data is done in the form of 2D graphs or 3D models defined using java-script.

- Participants: Fausto Lo Feudo, Huu Phuoc Nguyen, Patricio Inzaghi, Peter Sturm and Thomas Capelle
- Contact: Peter Sturm
- URL: https://gitlab.inria.fr/tranus/QGIS_Tranus_Reports

5.7. Comptabilité Ecologique

FUNCTIONAL DESCRIPTION: Databases, database handling tools and data visualization tools (on the web-site). Databases include socio-economic and environmental datasets. Visualization tools include interactive piecharts, maps and Sankey diagrams.

- Participants: Jean-Yves Courtonne and Pierre-Yves Longaretti
- Contact: Jean-Yves Courtonne
- URL: http://www.eco-data.fr

6. New Results

6.1. Calibration of the Tranus Land Use Module: Optimisation-Based Algorithms, their Validation, and Parameter Selection by Statistical Model Selection

Instantiating land use and transport integrated models (LUTI modelling) is a complicated task, requiring substantial data collection, parameter estimation and expert analysis. In this work, we present a partial effort towards the automation of the calibration of Tranus, one of the most popular LUTI models. First, we give a detailed mathematical description of the activity module and the usual calibration approach. Secondly, we reformulate the estimation of the endogenous parameters called shadow prices as an optimisation problem. We also propose an optimisation algorithm for the calibration of the substitution submodel, setting a base for future fully integrated calibration. We analyse the case of transportable and non-transportable economic sectors and propose a detailed mathematical scheme for each case. We also discuss how to validate calibration results and propose to use synthetic data generated from real world problems in order to assess convergence properties and accuracy of calibration methods. Results of this methodology are presented for realistic scenarios. Finally, we propose a model selection scheme to reduce the number of shadow prices that need to be calibrated, with the aim of reducing the risk of overfitting to data. This work is published in [2].

6.2. Convolutional neural networks for disaggregated population mapping using open data

High resolution population count data are vital for numerous applications such as urban planning, transportation model calibration, and population growth impact measurements, among others. In this work, we present and evaluate an end-to-end framework for computing disaggregated population mapping employing convolutional neural networks (CNNs). Using urban data extracted from the OpenStreetMap database, a set of urban features are generated which are used to guide population density estimates at a higher resolution. A population density grid at a 200 by 200 meter spatial resolution is estimated, using as input gridded population data of 1 by 1 kilometer. Our approach relies solely on open data with a wide geographical coverage, ensuring replicability and potential applicability to a great number of cities in the world. Fine-grained gridded population data is used for 15 French cities in order to train and validate our model. A stand-alone city is kept out for the validation procedure. The results demonstrate that the neural network approach using massive OpenStreetMap data outperforms other approaches proposed in related works. This work is published in [5].

6.3. Uncertainties of Domestic Road Freight Statistics: Insights for Regional Material Flow Studies

Freight statistics are at the core of many studies in the field of industrial ecology because they depict the physical inter-dependencies of territories and allow to link worldwide productions and consumptions. Recent studies have been increasingly focusing on subnational scales, often relying on domestic freight data. In this perspective, this article analyses the uncertainties of the French domestic road freight survey, road being by far the most common mode of transport in the country. Based on a statistical analysis of the survey, we propose a model to estimate the uncertainty of any given domestic road transport flow. We also assess uncertainty reduction when averaging the flows over several years, and obtain for instance a 30% reduction for a 3-year average. We then study the impact of the uncertainties on regional material flow studies such as the Economy-Wide Material Flow Analysis of the Bourgogne region. Overall the case studies advocate for a systematic assessment of freight uncertainties, as neither the disaggregation level nor the quantities traded are good enough predictors. This justifies the need for an easy-to-implement estimation model. Finally, basic comparison with the German and Swedish surveys tend to indicate that the main conclusions presented in this article are likely to be valid in other European countries. This work is published in [3].

6.4. A method for downscaling open population data

To extend our ongoing work on urban sprawl indicators (see above), we have developed a method to perform dissagregated population estimations at building level using open data. Our goal is to estimate the number of people living at the fine level of individual households by using open urban data and coarse-scaled population data. First, a fine scale description of residential land use per building is built using OpenStreetMap. Then, using coarse-scale gridded population data, we perform the down-scaling for each household given their containing area for residential usage. We rely solely on open data in order to ensure replicability, and to be able to apply our method to any city in the world, as long as sufficient data exists. The evaluation is carried out using fine-grained census block data for cities in France as ground-truth.

This work is published in [6] and the associated software implementation is made available as open source code at https://github.com/lgervasoni/urbansprawl.

6.5. Modelling the relationships between urban morphology, pollutant generation and concentration in the air using PLS path modelling

We have simultaneously modelled the factors that contribute to shaping the urban environment in terms of population density and activities and the level of land use mix on the one hand, and the mechanisms through which this urban morphology is linked to the emission of pollutants and their concentration in the air in the municipalities of the Auvergne-Rhône-Alpes region. To do this, we used the PLS path modelling approach,

which is a method of estimating structural equations to model the relationships between latent variables obtained by extracting the information contained in the multidimensional data used to measure them. This work was carried out as part of Diop Samba's internship [8].

6.6. Implementation of the World3 model in Python for parametric exploration

The 'World3' model is a digital tool for simulating long-term interactions between population, industrial growth, food production and the boundaries of terrestrial ecosystems. This model was developed in the 1970s. We have ported this model to a modern infrastructure (Python3 + related libraries), in order to be able to apply parameter learning, data analysis and sensitivity study techniques to it. This work was carried out as part of the internship of Aina Rasoldier.

7. Partnerships and Cooperations

7.1. Regional Initiatives

7.1.1. QAMECS / MOBIL'AIR : ATMOSPHERIC POLLUTION: Characterization of novel exposure markers, of biological, health, economic and societal impacts and evaluation of public policies

Project funded by ADEME, Grenoble metropolis, IDEX Université Grenoble Alpes
Duration: 2016 – 2022
Project coordinator : Remy Slama (INSERM) and Sandrine Mathy (GAEL, CNRS). Inria Coordinator: Emmanuel Prados
Other partners: Air Rhône-Alpes, CNRS, Sciences Po Grenoble, Inserm, IAB, Université Grenoble-Alpes
Abstract: Urban atmospheric pollution is one of the main threats to human health that can be to some extent controlled by public action. In Europe, many cities have implemented various types of low emission zones (LEZ, focused on traffic and heating emissions), France being a notable exception. Although fine particulate matter (PM2.5) is usually assessed through its mass concentration, other metrics, such as PM chemical speciation as well as the so far little considered oxidative potential (OP) of PM, are worth considering, both in terms of associations with human health and in the context of monitoring of the efficiency of LEZ. QAMECS covers all dimensions from atmospheric emissions, impact of meteorological conditions on air pollution human behaviours related to transportation, environmental levels, health, associated economic costs and societal awareness. The project relies on environmental measurements, modelling, repeated observational (representative) population studies, an existing mother-child cohort, a controlled human experiment, health impact and related economic assessment. It is conducted by a consortium of specialists of chemistry and physics of air pollution, economics, sociology, epidemiology, geography, in relation with local authorities. It will bring results important for urban planning, public health, and more fundamental research on the measurement of PM and assessment of their biological and health impact.

7.2. National Initiatives

7.2.1. AF Filières : Analyse des Flux des Filières biomasse pour des stratégies régionales de bioéconomie

Project funded by ADEME
Duration: 2017-2019
Coordinator: Jean-Yves COURTONNE (Equipe STEEP, Inria) [Emmanuel Prados (STEEP/Inria) for Inria partner]

Other partners: Equipe STEEP, Inria, Grenoble Rhônalpénergie-Environnement (RAEE), Lyon Laboratoire d'Economie Forestière (LEF), INRA / AgroParisTech Nancy.
Keywords: Environmental assessment, Ecological accounting, Material Flow Analysis, Sustainable supply chains, Multicriteria analysis.
Abstract: Flow analyses of biomass supply chains for regional bioeconomy policies. The goals of the project are the following:

- Improve knowledge on the material flows of the forest-wood and agri-food supply chains in France at national and regional levels,
- Provide a holistic vision of the situation by associating environmental and socio-economic indicators to material flows,
- Provide a more precise assessments (quantitatively and qualitatively) in the case of the Auvergne-Rhône-Alpes region.

8. Dissemination

8.1. Promoting Scientific Activities

8.1.1. Scientific Events Organisation

8.1.1.1. General Chair, Scientific Chair

- Denis Dupré, Pierre-Yves Longaretti and Emmanuel Prados are the Scientific Chair of the series of conferences entitled "Understanding and Acting"; see section 8.3.1.

8.1.1.2. Member of the Organizing Committees

- P. Sturm was member of the Organization and the Program Committees of the 2018 edition of the Inria Science Days (*Journées Scientifiques Inria*)

8.1.2. Scientific Events Selection

8.1.2.1. Member of the Conference Program Committees

- Emmanuel Prados was member of the Program Committees of the Workshop on "Information and decision-making systems and democracy" at the INFORSID 2018 Congress , Nante, France 28-31 May 2018.
- Emmanuel Prados was member of the Program Committees of the Workshop on "EIAH and sustainability" at RJC-EIAH 2018, Besançon, France 3-5 April 2018.

8.1.3. Journal

8.1.3.1. Reviewer - Reviewing Activities

- P. Sturm was reviewer for Environment and Planning B: Urban Analytics and City Science, International Journal of Computer Vision, and Journal of Mathematical Imaging and Vision.

8.1.4. Invited Talks

- E. Prados give an invited talk to the **Journées scientitifiques de l'Inria** "", Bordeaux, France, june 27-29, 2018. Organizers: Inria (http://journees-scientifiques2018.inria.fr/).
- E. Prados give an invited talk to the **LIED Thematic Seminar** "Effondrement, déclin ou catastrophologie ? : théories sur les risques et l'avenir des sociétés" (Laboratoire interdisciplinaire sur les énergies de demain) with Pierre-Yves Longaretti and Grégoire Chambaz, Paris, France, June 19, 2018. Organizers: Petros Chatzimpiros.
- E. Prados give an invited talk to the **round table** on military nuclear [links with the risk of collapse of modern society] at the **first anniversary of the "Nuclear Knowledges" program**, Science Po, Paris, France, May 31, 2018. Organizers: Benoît Pelopidas.

- E. Prados give an invited talk to the **Conference for the Société Francaise de Physique** : "Vers un effondrement de notre société moderne ?", Grenoble, France, June 7, 2018 ; Conférence with Pierre-Yves Longaretti. Organizer: Thomas Thuillier.

8.1.5. Research Administration

- P. Sturm is, since 2015, Deputy Scientific Director of Inria, in charge of the domain Perception–Cognition–Interaction
- E. Prados was in charge of the working group "Digital tools for the progress of society" for the Strategic Plan of Inria, 2017-2018. His work resulted in the writing of the Scientific Challenges entitled "Digital world, society, and complexity".

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

As teacher-researchers, Denis Dupré and Serge Fenet completed their full teaching service in 2018 (full-time) in their field of study. Regis Perrier did a half service.

8.2.2. Supervision

PhD : Luciano Gervasoni, *Contributions to the formalization and implementation of spatial urban indices using open data: application to urban sprawl studies*, University Grenoble Alpes, November 19th, 2018, Peter Sturm (supervisor) and Serge Fenet (co-supervisor).

PhD in progress : Michela Bevione, *Socio-ecological transition, wealth creation and territorial metabolism: the case of Maurienne Valley*, October 2016, Pierre-Yves Longaretti (co-supervisor) and Nicolas Buclet (supervisor). Phd thesis in collaboration with the PACTE Laboratory. This interdisciplinary research on territorial ecology aims at bridging the gap between quantitative modeling and socio-economic and qualitative approaches to better understand the interactions between human society and the environment.

8.2.3. Juries

- P. Sturm chaired the Habilitation committee of Rémi Boutteau (Normandie Université, president), was reviewer of the PhD theses of Laura Fernàndez Julià (Université Paris-Est) and Mathias Gallardo (Université Clermont Auvergne) and chaired the PhD committee of Fatima Aziz (Université de Limoges).

8.3. Popularization

8.3.1. Conferences "Understanding and Acting" :

Saving Civilization is not a spectator sport
Lester Brown

Following a dynamics of exponential growth in a finite world, humanity today faces a number of unprecedented and tightly interlinked challenges. With a growing number of environmental limits being largely and irreversibly exceeded (GHG concentrations in the atmosphere, biodiversity loss, soil erosion, freshwater shortages...), social, economic, geopolitical, humanitarian (etc.) consequences are becoming more urgent than ever to address, while the threat of an uncontrolled global collapse is now more than a prospect. It is urgent to initiate deep, structural, socioeconomic changes on virtually all aspects of our increasingly global societies (economics, industrial and agricultural production, consumption, education, all requiring major new local and global policies).

In view of these facts, the STEEP research team has initiated in 2016 a series of conferences-debates entitled "Understanding & Acting" ("Comprendre et agir") that examines these issues in order to help researchers and citizens to increase their awareness of the various issues at stake in order to initiate relevant individual and collective actions. From now on, the scientific community at large must realize that its duty also lies in helping citizens to better understand these issues. If the fraction of people in society whose privilege is to be paid to think about society's problems do not seize this opportunity in the critical times we face, who will? Researchers must become more involved in the search of socioeconomic alternatives and help citizens to implement them. The interactions between researchers and citizens must also to be reinvented.

The presentations of this series of conferences typically last between 30 to 45 minutes; they are followed by a 45 minute public debate with the audience. The presentations are captured on video and then made directly accessible on the YouTube Channel "Comprendre et Agir". At the end of 2017 the YouTube channel reached almost 45,000 views with a rate of integral viewings re¬maining at above 25%.

Examples of conferences given in 2016-2017:

- "Why and how to recognize money as a common good?" by Jean-Michel Servet, Graduate institute of international and development studies (IHEID) at Genève.
- "What alternative to the crisis of representation?" by Loic Blondiaux, University of Paris I Panthéon-Sorbonne.
- "Reinventing agriculture and food in the 21st century?" by Gilles Billen, CNRS.
- "Can the commons movement re-activate democracy? by Christian Laval, University of Paris Ouest Nanterre La Défense.
- "Limiting climate change: Why do we not do it?" by Denis Dupré, University of Grenoble Alpes.
- "Understanding society collapses. What future for ours? " by Emmanuel Prados, Inria.
- "Environment, economy, collapse: squaring the circle?" by Pierre-Yves Longaretti, CNRS.

Link to the web page of the series [program, abstracts, dates, complements etc.]:
https://team.inria.fr/steep/les-conferences-debats-comprendre-et-agir/
Link to the YouTube channel :
https://www.youtube.com/channel/UCJbcXCcOA63M8VMysAbmt_A

8.3.2. Other popularization activities :

- Emmanuel Prados was guest speaker at
  - the **public debate "defying disaster"** that held at Grenoble City Hall., Grenoble, France, 13 December 2018. Organizers: City of Grenoble. "Climat, défier la catastrophe : vers un nouvel humanisme"
    http://www.grenoble.fr/uploads/Externe/a1/757_069_Conference-Climat-defier-la-catastrophe-vers-un-nouvel-humanisme.pdf
    Video of the conference on YouTube : https://www.youtube.com/watch?v=IfvFHx0kYa0
  - the **exchange day on travel modelling in Grenoble** "", Grenoble, France, 5 October 2018. Organizers: Agence d'urbanisme de Grenoble.
  - the **Controversation** entitled "Digital technology in the face of environmental impasse: an exit door or a way forward?", Aix en Provence, France, 17th of February 2018. Organizers: association "Tous Chercheurs" in collaboration with the students of the School of Journalism and Communication of Aix-Marseille ; Amina Mokrane.
  - the **Opening Conference at the Alterre Day** «Voyages en transitions » : "De l'urgence de tout changer face à l'effondrement qui vient", Dijon, France, March 21th 2018. Organizers: Alterre Bourgogne-Franche-Comté (Agence régionale pour l'environnement et le développement soutenable) ; Fabienne Lapiche-Jaouen.
    https://www.alterrebourgognefranchecomte.org/c/agenda/10604/journee-alterre-sur-le-theme-des-transitions?

- Emmanuel Prados participated **Fictionnalisation de controverse** in the research-action project FORCCAST. 22 April, 2018, Paris.
- Emmanuel Prados gave a conference at **STMicroelectronics Grenoble** : 'Collapse: understanding and accepting the game over of our modern society", Grenoble, France, March 8 2018. Organizers: Philippe Vincent and Violaine Pasini.

9. Bibliography

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International Conferences with Proceedings

[4] T. BIRDAL, B. BUSAM, N. NAVAB, S. ILIC, P. STURM. *A Minimalist Approach to Type-Agnostic Detection of Quadrics in Point Clouds*, in "CVPR 2018 - IEEE Conference on Computer Vision and Pattern Recognition", Salt Lake City, United States, June 2018, pp. 3530-3540, https://hal.inria.fr/hal-01855977

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Conferences without Proceedings

[7] S. CARRARA, M. BEVIONE, H. S. DE BOER, D. GERNAAT, S. MIMA, R. C. PIETZCKER, M. TAVONI. *Exploring pathways of solar PV learning-by-doing in Integrated Assessment Models*, in "3rd AIEE Energy Symposium on Current and future challenges to energy security-the energy transition", Milan, Italy, Associazione Italia Economisti dell' Energia, December 2018, pp. 1-18, https://hal.archives-ouvertes.fr/hal-01960855

Other Publications

[8] S. F. DIOP. *Modélisation des liens entre la morphologie urbaine, la génération de polluants et leur concentration dans l'air par l'approche PLS path modelling*, Université Grenoble Alpes, September 2018, https://hal.inria.fr/hal-01880194

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[10] L. REZAKHANLOU, S. FENET, L. GERVASONI, P. STURM. *USAT (Urban Sprawl Analysis Toolkit) : une plateforme web d'analyse de l'étalement urbain à partir de données massives ouvertes*, in "Atelier Démo de la conférence SAGEO (Spatial Analysis and Geomatics)", Rouen, France, November 2017, https://hal.inria.fr/hal-01610738