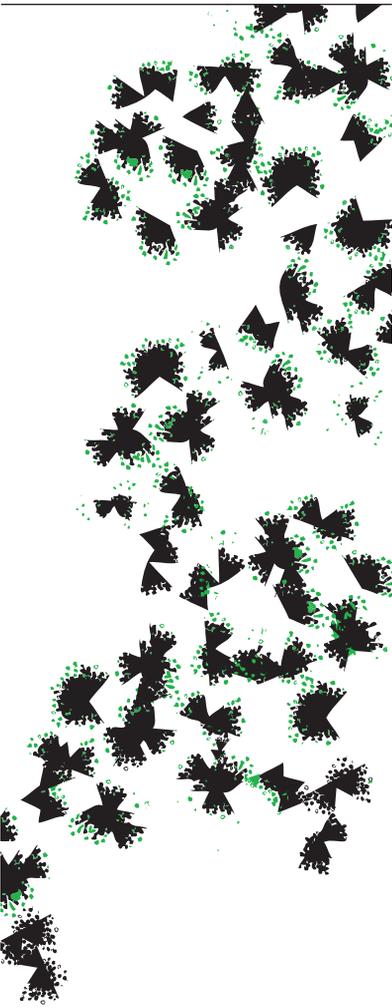


**INAUGURAL LECTURE**  
18TH FEBRUARY 2016

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SYSTEMS AND  
SUSTAINABILITY  
IN TIME  
AND SPACE

**PROF.DR. ALEXEY VOINOV**

**UNIVERSITY OF TWENTE.**



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# SYSTEMS AND SUSTAINABILITY IN TIME AND SPACE

Inaugural lecture given to mark the assumption of the position as professor of Spatio-Temporal Systems Modeling for Sustainability Science at the ITC at the University of Twente on Thursday 18th February by

**PROF.DR. ALEXEY VOINOV**

# SYSTEMS AND SUSTAINABILITY IN TIME AND SPACE

**Mijnheer de Rector, collega's, familie en vrienden,**

## **INTRODUCTION**

"May you live in interesting times" is an English expression purported to be a translation of a traditional Chinese curse. The Chinese do not seem to accept their authorship. But nevertheless the meaning remains quite relevant. We certainly are living in interesting times. Over just my lifetime the human population has tripled. The International Geosphere-Biosphere Programme (IGBP) has called the last 60 years the period of Great Acceleration<sup>1</sup>. The land cover has been vastly changed by human activity. Clearly connected to that is the massive species extinction. Scientists are talking about the sixth mass extinction in the history of Earth – the first since the cataclysm that wiped out the dinosaurs some 65 million years ago (Barnosky et al. 2011). By one estimate, Earth has lost half of its wildlife during the past 40 years (Ceballos et al. 2015). During this time there were no geological cataclysms of any large scale. No devastating eruptions, or asteroids hitting the planet. Nothing - except human activity. The current ratio of the biomass of wild terrestrial vertebrates to that of humans together with the domesticated livestock that they keep is about 1:60. 10,000 years ago this was 200:1. This is a 12,000 times change (Smil 2011; Smil 2015).

Climate change is yet another "interesting" process that humans have triggered. It was almost 200 years ago when Edme Mariotte, Horace Benedict de Saussure, Fourier and Poulliet did their experiments, collected data and laid the foundation for some theoretical generalizations. Arrhenius in 1895 already gave a talk to the Swedish Royal Academy "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground". In 1938 Guy Stewart Callendar showed that global warming could be brought about by increases in the concentration of atmospheric carbon

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<sup>1</sup> <http://www.igbp.net/globalchange/greatacceleration.4.1b8ae20512db692f2a680001630.html>

dioxide due to human activities, primarily through burning fossil fuels. These findings were based on some simplified theoretical models, which have been consistently improved during the 20th Century, incorporating more details and mechanisms, culminating in a dozen or more Global Circulation Models (GCMs) designed to understand global climate in as many details as possible and to predict its possible future. By now there are at least some 20 models used for climate prediction around the world, with the same acronym, they are now called Global Climatic Models. By the 1990's it became quite clear: increased CO<sub>2</sub> and other GHG concentrations lead to global warming, and we are rapidly increasing the amount of CO<sub>2</sub> in the atmosphere by burning huge amounts of fossil fuels. The system is complex, and there are many uncertainties that we cannot yet exactly account for. But the general trend is hard to deny. That was clear almost 25 years ago. Yet up to date if there is any action taken it is hardly adequate to mitigate or adapt to climate change. Moreover there is an active resistance and denial of climate science, where system complexity and the uncertainties are used as the main excuse for lack of action.

The September 2015 Royal Geographical Society annual general meeting was dedicated to the proposition that earth has been so profoundly influenced by humans that a new geological period – the Anthropocene – should be recognized (Verburg et al. 2015). Unfortunately this Anthropocene does not look very much like the Noosphere that Vladimir Vernadsky and Pierre Teilhard de Chardin have envisioned (Vernadsky 1945). Vernadski saw the Noosphere as the reign of human mind, consciousness, wisdom, and intellect<sup>2</sup>. Clearly the anthropocene is not quite that. Humanity indeed does appear as a 'geological' force, capable of change that can be compared to processes of geological scale such as volcano eruptions. This has been recently confirmed during the eruption of Eyjafjallajökull in Iceland. According to David McCandless, the CO<sub>2</sub> emitted by that eruption has been entirely compensated by the air traffic shutdown due to dangerous levels of volcanic ash in the atmosphere. In a way, we have witnessed the first CO<sub>2</sub>-neutral volcano eruption on this planet<sup>3</sup>. Vernadsky has foreseen this geological scale of human activity back in 1920s. He did expect also that these powers would be backed by collective consciousness and responsibility, through the interaction of human minds. Something we are still lacking today.

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2 [http://www-ssg.sr.unh.edu/preceptorial/Summaries\\_2004/Vernadsky\\_Pap\\_ITru.html](http://www-ssg.sr.unh.edu/preceptorial/Summaries_2004/Vernadsky_Pap_ITru.html)

3 [http://www.ted.com/talks/david\\_mccandless\\_the\\_beauty\\_of\\_data\\_visualization](http://www.ted.com/talks/david_mccandless_the_beauty_of_data_visualization)

There is growing social unrest in many regions on the planet. Much of that is already connected to changing climate and general depletion of natural resources. Even the recent conflict in Syria has been evolving on a background of an unprecedented draught, which probably contributed to the social conflicts creating the refugee crisis that has now reached our neighborhoods (Kelley et al. 2015). As illustrated by the 2014 IPCC report, climate change will reinforce inequalities, both within and between countries<sup>4</sup>. As reported recently by the Oxfam foundation, inequalities have risen to the level when 62 (sic!) individuals on this planet possess half the wealth, and 1% of the richest people own as much as the remaining 99%<sup>5</sup>. What we also see is that there appears to be pretty strong negative correlation between the income gap and the expenditures on environmental protection, which also translates into the ability to act of climate change. The New Economics Foundation shows how there are clear positive feedbacks that through lobbying, tax evasion, or corporate capture reduce public expenditures, and heavily limit the State's capacity to deliver public goods<sup>6</sup>.

On the positive side we see some indication that the era of fossil fuels may be at its dawn. Renewables in China are growing so fast that it appears that indeed the country can meet its CO<sub>2</sub> reduction targets, which are quite ambitious. There are growing health concerns related to air pollution. This also helps to wean China off the fossil fuel treadmill. A recent report shows that electricity generation based on coal continues to decline in the US: it fell from 39% in 2014 to 35% in 2015<sup>7</sup>. Yet, although our understanding of environmental processes as well as the knowledge on interactions in socio-environmental systems is increasing, our ability of making the right decisions is still limited. We know a lot about the climate change and global change and know how it can impact our livelihoods. We already see what are the possible conflicts due to limited resources such as food, energy and land. We realize how loss of biodiversity and ecosystem function can be detrimental to our life-support systems. However, in all these cases we still fail to make the necessary steps to avoid or to adapt to these changes. There are many examples when knowledge and understanding does not

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4 <http://www.ipcc.ch/report/ar5/wg2/>

5 <https://www.oxfam.org/en/research/economy-1>

6 <http://www.neweconomics.org/blog/entry/energy-round-up-more-inequality-less-climate-action>

7 [http://www.bcse.org/wp-content/uploads/BCSE-2016-Sustainable-Energy-in-America-Factbook\\_Executive-Summary.pdf](http://www.bcse.org/wp-content/uploads/BCSE-2016-Sustainable-Energy-in-America-Factbook_Executive-Summary.pdf)

necessarily produce adequate (re)action in form of policies or management strategies.

There are growing issues with overall effectiveness of science in producing adequate policy and action. As the size of the human ecological footprint grows, as the complexity of our societies increases while processes and interactions accelerate and become more dangerous and irreversible, the policy-making remains slow, and actually decelerates as more democratic institutions are installed. While science was and still is extremely powerful in developing new technologies and helping the humans to grow and conquer, it seems to remain quite weak and confused when we need to persuade people to slow down, to change behavior, to change priorities and values.

# SYSTEMS AND MODELS

My excitement about models dates back to some of the first projects by the Club of Rome, in particular, the World2 model by Jay Forrester and the later implementation by Denis Meadows and colleagues that we now know as the World3 model. The models presented the whole world as interplay between five major sub-systems: human population, food, industry, non-renewable resources, and pollution. World2 was the bare-bones version with just 5 state variables. It was then further detailed with new processes and variables added. The World3 model and the results got published in a book, "Limits to growth", which became a bestseller (Meadows et al. 1972). The most striking and disturbing conclusion was that the generally accepted expectation of infinite economic growth was not realistic. It was quite fascinating how a computer model could be used to look into the possible human futures. This largely convinced me that computer modeling is what I want to do.

My first model had four, then, later, five state variables. It was a model of a lake. We could qualitatively describe the process of eutrophication in a small lake. We could even generate the hysteresis effect that is actually observed in real lake ecosystems, when the nutrient loading is gradually increased and at some point the system flips from an oligotrophic, low algae state to a eutrophic, algae bloom condition. The model was good to understand the qualitative behavior, but it was certainly way too simple, aggregated and general to make any sort of meaningful management decisions. One other, subjective decision that was playing its role in this case was that we wanted to treat the model analytically; therefore adding more complexity was not possible just because I wouldn't be able to do the math any longer. But if we do computer simulations, we are no longer restricted by analytics. We have numeric methods to solve equations and the computer can certainly handle much more complexity than a human with a pen and paper.

So the next model I've built was for a real lake - Lake Balaton in Hungary. And now it was computer simulation only, so no need to restrain yourself when adding more variables and processes. The model turned out to be more complex than the World3 model, including a module for wind-

induced currents and hydrodynamics that mixed the lake and moved stuff around. Everything seemed pretty important if we want to understand what causes the algal blooms. But what next? Can you actually use the model to make some management decisions? Well... maybe, but there are still so many unknowns and uncertainties. Moreover it became only more evident that it is the watershed that determines the fate of water quality in an aquatic system. In fact this is something that could be pretty obvious even from the very simple lake models. No matter how high is the buffering capacity of a lake, if we continue to dump waste and nutrients into it the algae will start blooming. But when such results are output from a real model, they suddenly seem to be gaining some additional weight and authority. If they are not exactly welcome, like when we show that the state of the Lake is a function of the intensity of farming on the watershed, immediately the model starts to attract more suspicion and scrutiny.

This we also saw with World3. The human predicament it outlined was not a very rosy one, so non-surprisingly the model was widely criticized (Cole et al. 1973). Today, something similar is happening with Global Climate Models, GCMs. If the results are not nice - there better be something wrong with the model. Most of the criticism about any model usually comes from the assumptions it makes, from what is included and what is not. On the one hand, by definition, models are simplifications, abstractions of reality. This means that certain things are necessarily ignored, or averaged in a model. If too little is considered in a model, the picture becomes skewed, one-sided, or inadequate. If too much is included in a model, it can become so complex that it hardly helps understand the system, even if it is run on a computer. It also becomes difficult to communicate results to the end users, who then become easily upset that they do not understand what is going on, and that there is too much uncertainty in the model. A good model is always a compromise between more detail, more factors, and more complexity included, on the one hand, and a better understanding of how these factors actually interact that comes from careful model analysis, which is possible only when the model is not too complex.

Simplifications in modeling are a must. The decision about what and how is included in a model is made by the modelers, by those who actually build the model. Can we then claim that these decisions are always objective? Scientists are also humans. Humans are subjective. We may include certain

processes in our assessment because we think they are important, or we simply know more about these processes, while we are ignorant about some other ones, or even because we are particularly interested in the effects that these particular processes may have on the system. Humans may be biased. They may have vested interests.

But then the only way to know whether a model is a good one or not, is to see how it compares with reality and how its users can benefit from it. From this point of view the World3 model has performed remarkably well. A recent analysis compared 30 years of historical data with various scenarios considered in the model. Key features of a business-as-usual scenario, called the "standard run", compared quite favorably. This scenario results in collapse of the global system midway through the 21st century. The data do not compare well with other scenarios involving comprehensive use of technology or stabilizing behavior and policies (Turner 2008; Turner 2014). But does this mean that we have to wait for an event to actually happen to prove that the model predicting it was correct?

My next large model was a landscape scale simulation for the Patuxent watershed in Maryland, USA. Here we considered plant growth, nutrients in surface and subsurface flows, dead organic material and hydrology (surface and groundwater) with the goal to see how various types of landuses translated into the amounts of nutrients entering the estuary, which was the Chesapeake Bay in this case. The model was an extension of the so-called General Ecological Model (GEM) and the idea was quite simple: you run a local unit model in each of the grid cells that represent the landscape, and then apply the hydrology model to move the constituents between cells (Fig. 1). The GEM model itself was quite complex and calibrating and testing it already was quite a pain. Doing this as part of the Patuxent landscape model (PLM) that contained about a thousand cells was getting very difficult. Moreover at some point you seem to lose track of what is happening in the model: some totally unexpected behavior starts to emerge and debugging and tracing back all the influences becomes a very costly task.

One idea was to break up the GEM model into modules that could be considered separately. For example, we do not need detailed information about water quality to calibrate the hydrology component. Similarly, we can parameterize the vegetation and have some preliminary calibration

done for water quality without necessarily running the detailed model for plant growth. This modular approach worked and the model eventually was calibrated and performed quite well (Voinov et al. 2004).

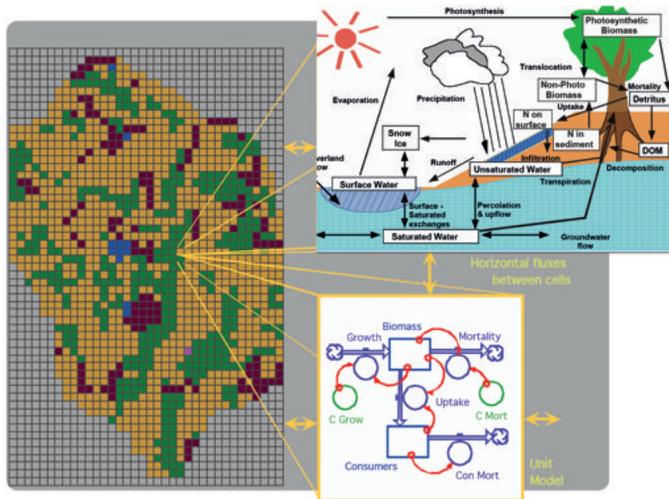


Figure 1. Spatial implementation of a dynamic watershed model.

Jumping a bit ahead let me mention that the idea of modularity in modeling has later become widespread<sup>8</sup>. Moreover now we are talking about model integration, when we are trying to make independently developed models talk to each other and interact in a meaningful way. This means that we do not need to build new models for various systems and processes. Ideally we can just browse model repositories to find if something relevant has been already developed and archived, and then assemble new models from such components. While this sounds really promising there is certainly still a lot of caveats to be sorted out. One of my projects, COMPLEX, supported by the EU FP7 framework, is exactly about model integration. Here, with Getachew Belete and help from Rolf de By, we are exploring how to make sure that the components properly exchange data, that they are semantically in tune, meaning that when they are exposing a certain data set, its meaning is properly recognized by other models, that they are talking the same language, using the same terms, properly conveying

<sup>8</sup> See for example the Community Surface Dynamics Modeling System - CSDMS - [http://csdms.colorado.edu/wiki/Main\\_Page](http://csdms.colorado.edu/wiki/Main_Page)

and recalculating the units and resolutions used, while the modeling paradigms and assumptions are also congruent and are not mutually contradicting. In short, how do we make sure that we are not producing 'integronsters' (Voinov & Shugart 2013) - integrated models that appear to be correct in terms of the components that are put together, but turn out to be wrong or ridiculous if we look a bit deeper into the content? These integration techniques are now also applied in collaboration with the CSTM Department at UT and with TNO to link various energy related models for COMPLEX.

But going back to PLM. The model was modularized and calibrated in a hierarchical way, moving from small subwatersheds, to larger ones, from just one structural module (say, hydrology) to the full model, under various spatial resolutions largely depending on the data that was available. It was compared to a suite of other models developed for the same watershed and did quite well.

It might be worthwhile to note here that the Chesapeake Bay has been showing signs of degradation for decades. There were lawsuits and there was demand for action. Billions of dollars have been poured into research of the Bay. Expensive monitoring and modeling was undertaken, and even more expensive remediation projects were launched. Scientific understanding of the causes and consequences of eutrophication in the Bay certainly progressed a lot with new findings, new understanding and new hypotheses that have been formulated and tested. What was missing is the improvement of water quality in the Bay.

There are many model developed for the Bay. Over the past three decades, the Chesapeake Bay Program has developed a complex, multi-component modeling system that it now uses as the foundation for its assessment of restoration progress, the Chesapeake Bay Modeling System (CBMS). The CBMS is composed of three core components: An airshed model, a watershed model and an estuary model. In addition, a land use change model and a program called "Scenario Builder" are used to generate inputs to simulate past, present and future states of the Chesapeake Bay watershed. So there was never a lack of modeling for the Bay and there were always plenty of models to compare with.

Having good modeling and simulation tools really helps. The PLM was implemented in the Spatial Modeling Environment (SME) developed back in the 1990s. SME embedded the unit dynamic models developed in Stella into a spatial context, connecting them with spatially heterogeneous data sets stored in a GIS. Now there are some very promising developments that should allow a seamless connection of dynamic modeling with GIS capabilities<sup>9</sup>. Perhaps the ILWIS 4 New Generation implementation, an open source GIS platform developed by ITC under the skillful management of Rob Lemmens, will eventually allow us to conduct modeling in time and space within the framework of one platform.

So the PLM model was built, calibrated, published, and presented to various stakeholder groups (Voinov et al. 1999). The model was performing well, in terms of matching some data. However, does this make it a good model? It was disappointing to see that it remained unclear how the model results were to be used, how they were to be acted upon. We could see that increasing complexity of models used for coping with the complexity of the systems we analyze, did not necessarily produce the kind of understanding that is appropriate for action. We seemed to be treating complexity with complexity, while the real power of modeling is simplification and the ability to abstract to a higher level of analysis, where the solutions may be easier to identify and communicate. According to Einstein “problems cannot be solved at the same level of awareness that created them”. Yet it is not clear how to navigate over the hierarchies of models and how to choose the appropriate scale and resolution in time, space and structure (complexity) to make our models used and to actually instigate action.

Moreover, in socio-environmental modeling we are dealing with open and evolving systems. When modeling open systems we have to cut certain relationships to the ‘outside world’, and replace them with fixed forcings, while in reality in many cases there are feedbacks, which we simply cannot afford to take into consideration. When we model evolving systems we can only look at the system in the past, and assume that the same structure and processes will continue in the future. This is certainly wrong, and many systems change while we study and model them. This is especially clear with social systems, where, for example, only by asking a certain question during a survey, we can already change the attitudes and perceptions of people and get an entirely wrong picture of the current state. Some local

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9 <https://vimeo.com/user29453510/review/153355429/1c1a97df84>

people may have never thought about using a certain ecosystem service until the researchers asked them about it. Now that they learn about this ecosystem service they may start harvesting it, while in the survey their response was negative. As in quantum physics, it becomes impossible to separate the scientific observer from the observed phenomenon<sup>10</sup>.

So from some very complex models I have then jumped back to some fairly simple ones that would operate in terms of a couple of general indicators. For example in energy analysis it has been shown that simply calculating the output energy is not really enough. What matters is the net energy produced. In much too many analyses we are focusing on what may be produced, the potential for energy production, forgetting how much will we need to spend to deliver that energy. A good indicator to look at is the Energy Return on Energy Invested or  $EROEI = \text{Energy out} / \text{Energy used}$ . Together with several MSc students (Oludunsin Arodudu, Melese Firrisa, Esther Ibrahim), Iris van Duren and Javier Morales, we have applied extended Life Cycle Assessment in combination with GIS to analyze the potential of various bioenergy options in the province of Overijssel and elsewhere (Fig.2) (van Duren et al. 2015; Arodudu et al. 2013; Voinov et al. 2015).

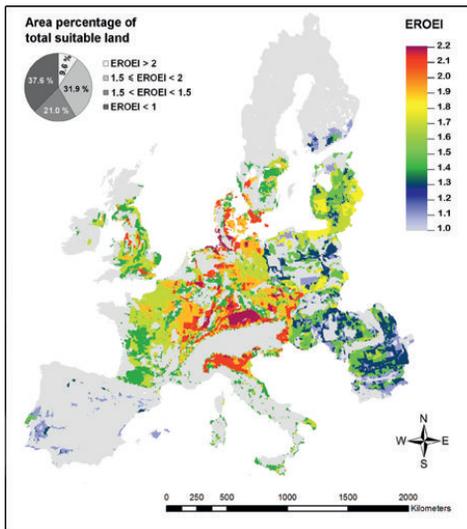


Figure 2. Distribution of EROEI for rapeseed biofuel production in Europe.

10 Weizmann Institute Of Science. "Quantum Theory Demonstrated: Observation Affects Reality." ScienceDaily. [www.sciencedaily.com/releases/1998/02/980227055013.htm](http://www.sciencedaily.com/releases/1998/02/980227055013.htm) (accessed February 9, 2016).

My transition to energy related problems was already largely stimulated by one of the projects that I was working on at the Army Corps of Engineers during my AAAS Science and Policy fellowship. That was on the energy-water nexus. The Army Corps is responsible for managing most of the waterways and water protection systems in US. At some point they have realized that there is a lot synergy between the conditions of the waterways and the energy production infrastructure (Fig.3). Everything is connected. If we had infinite energy we could produce as much water as we need (e.g. by desalination). Problem is that in many cases we need water to produce energy - certainly in hydropower, but also for cooling in nuclear and conventional fossil fuel installations (Voinov & Cardwell 2009).

In yet another spin-off of spatial analysis, we have been looking at the problem of constantly growing number of scooters in the Netherlands. The scooters impose really bad externalities. They are a health hazard, they create disproportional amounts of nasty pollutants and traffic accidents, and they are noisy and irritating. Above all, the existing infrastructure that puts them on bike lanes and in immediate vicinity of the lungs of bike riders is especially disturbing. So with my MSc students (Hanneke Hogenkamp and Thomas Steenbergen) together with Javier Morales we have looked at mapping and modeling the scooter distribution in Enschede and Amsterdam (Fig. 4). The results were not very encouraging, showing that, provided existing growth trends continue, up to 40% of the population will be adversely affected by scooters.

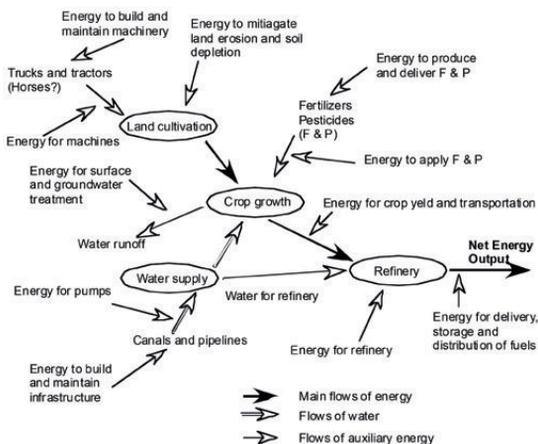


Figure 3. The life cycle of energy from biomass production.

But so what? It bothers me most in the research conducted that there is still a disconnect between our models and results, and the real life, the decision and policy-making, the behavior of people, the actions they take. Models and simulations are very useful for understanding of complex systems and for synthesizing knowledge about complex socio-environmental systems. But what are the models that can stimulate action and can make a difference? We lack a mechanism of communicating our results to people. We still need to understand how groups of people or societies as a whole take decisions, and what role can models play or should play in this process.

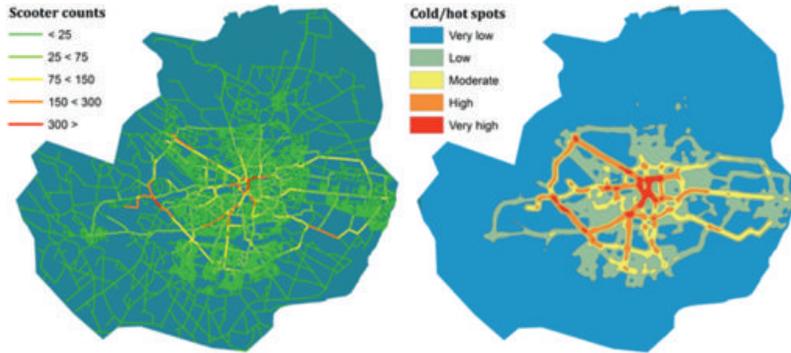


Figure 4. Modeling the distribution of scooters in Enschede.

Did the western or perhaps global society grow too complex to take tough decisions? Is action not taken because of inflexibility of the societies? Or is it because of specific ways that the societies have been organized that prevent us from taking action? Is this in the human genome, or is it in the social networks? Why people seem to be able to make the right decisions in the level of individuals, families and even small groups, but seem to fail miserably and consistently in larger scales, especially in the global scale?

One way to tackle these questions is to start modeling human society itself. Something we are trying to do with Tatjana Kuznetsova in application to agro-ecology. Here we are looking at how clusters of farmers and their networks can improve the overall efficiency of small-scale family farming. Can their sharing of knowledge and resources compensate for the lack of economy of scale that is driving the success of conventional industrialized farming? How will this comparison look when we become more limited

in our access to cheap fossil fuel energy? What are the optimal spatial arrangements for such farm clusters? How can we properly account for the ecosystem services that agro-ecological systems generate and add them to the bottom line of farm operations?

There are many types of models that we should consider to choose the most relevant ones for acting on global change and for steering toward sustainable development. However the curse of complexity and uncertainty chases us in all steps and implementations. Can we prove that models are useful? In principle yes, but only, if models did simplify the problem, in a sense that one can derive knowledge on a higher level of abstraction. This however is only partly true, because inevitably models do have their weaknesses, uncertainties, flaws and possibly also bugs. All these are again good arguments for not taking actions. So, yes models clearly help spread the message and support findings, especially if they convey a simple story, which means a synthesized aggregated summary of complex feedbacks, but models themselves are not enough for real decisions to be derived. A systems approach also helps in sorting out the meaning of some important concepts, such as sustainability, for example.

# SUSTAINABILITY

Sustainability is a tricky concept. For one thing, there is really no clear and generally accepted definition. People tend to define sustainability in ways that suit their particular biases, goals, priorities and vested interests, and often use the term with no explicit evidence and recognition of the exact meaning being implied. Sustainability became fashionable after the Brundtland Commission (Fig.5), which came up with one of the basic definitions. The Commission defined sustainable development as that, which meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland 1987).

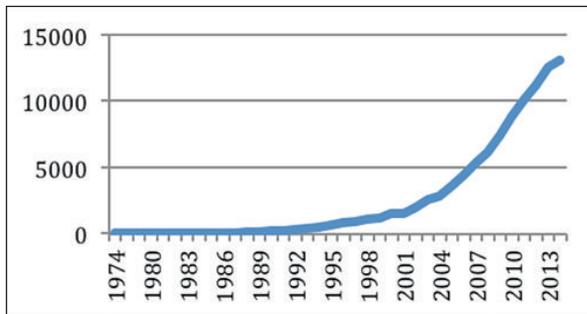


Figure 5. Dynamics of publications on 'sustainability' as documented by ScienceDirect.

Here immediately we run into a couple of problems in time and space, which seem to be often swept under the carpet. The Commission is talking about **needs**. Needs are things that we must have to survive. Needs are not only the basic physiological requirements for survival. Maslow came up with a whole pyramid of needs, which includes such entries as love, esteem, and self-actualization. But still needs could probably be satisfied quite easily for everybody on planet Earth.

Consider the recent, 2014, IMF data for per capita GDP. The world average is \$14,982. This is quite close to the GDP for Costa-Rica (\$14,919)<sup>11</sup>, which also has the 13th highest life satisfaction indices in the world<sup>12</sup>. It would

<sup>11</sup> [https://en.wikipedia.org/wiki/List\\_of\\_countries\\_by\\_GDP\\_%28PPP%29\\_per\\_capita](https://en.wikipedia.org/wiki/List_of_countries_by_GDP_%28PPP%29_per_capita)

<sup>12</sup> [https://en.wikipedia.org/wiki/Satisfaction\\_with\\_Life\\_Index](https://en.wikipedia.org/wiki/Satisfaction_with_Life_Index)

be reasonable to assume that in a country that has high life satisfaction, at least the basic needs should be met. So in the global scale, there is actually no poverty. Similar calculations can be made in terms of per capita calories produced. We already produce enough (and even more than enough) to feed the existing human population, assuming that we can have the same access to natural resources as today. It appears that today the sustainability problem, assuming the standard definition, is largely the wealth distribution problem. If wealth were distributed equally around the globe there would be no poverty, no hunger, no malnourishment and premature death. For US this would mean cutting the consumption in GDP terms by about 72%, while life satisfaction were to go up by 10 points. For Netherlands - by 69%, while life satisfaction would remain about the same (2 points up). Are we ready for that? Perhaps not quite. Just imagine a politician suggesting this in his/her election campaign...

Needs are very different from wants. A want is something that we desire to have, that we may, or may not, be able to obtain and can certainly survive without it. However, wants and needs are quite inseparable. Needs grow out of wants<sup>13</sup>. Needs are not static, some wants gradually turn into needs. "Haves" also become "needs". If you never had an Internet connection, you could not care less about it. Once you get used to fast Internet, finding yourself offline becomes almost a painful experience. Moreover, there is a positive feedback: the more we have, the more we need, the more we need, the more we want, the more we want, the more we have. The needs of Donald Trump are certainly very different from the needs of Mother Theresa. Even for the same person, needs change during the course of life. The needs of a 20 year old are likely to be quite different from the needs of the same person at the age of 80. How do you then tell people that they need to cut their needs in half to make sure there is enough for everybody?

These dynamics and variations of needs make things quite confusing. How can we possibly know what will be the needs of future generations if we cannot even be sure about our needs today? How can we make sure today that we will be able to meet the needs tomorrow? Which needs of today should we meet? Needs of whom? Or as Matthew Chew from Arizona State University eloquently puts it: "...it's naive to project our values, preferences and capabilities (maybe even our anatomies and physiologies) into an unknowable future and seek to impose them on our

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13 James Burns, 2007. Transforming Leadership. Grove/Atlantic, Inc., - Political Science - 336 pages

successors... Most of us are so decoupled from even the previous two or three generations to have much more than the most general idea what futures they were hoping for on our behalf. It isn't clear what ought to be sustained. It's even less clear what CAN be sustained" (ECOLOG mail list).

Moreover, already today, spatially the needs are very different and heterogeneous. They change across cultures, along gradients of wealth, education, or religion. A car is probably a need in the USA, especially in certain localities, where public transportation is non-existent. You will not be able to buy your groceries if you don't have a car. Our needs become shaped by the infrastructures that we developed. It is not surprising that the first question asked in the Ecological Footprint calculator<sup>14</sup> is "Select your location". If you are a vegan who never flies, drives, eats locally produced food and lives in a small 'green' house but live in USA, you will still need 3.2 planets to support your lifestyle. So what are the needs then that we are to consider when deciding about sustainable development: the needs in America, or the needs in Bangladesh? Or even within the continental US, the needs in Ferguson, Missouri (population 21,000, 67.4% black, per capita income \$20,472, persons below poverty level - 24.9%, unemployed - 13%) or the needs in Piedmont, CA (population 11,236, 1.3% black, per capita income \$98,949, persons below poverty level - 4.1%, unemployed - 5.7%<sup>15</sup>). Globally it is even more different and patchy, which means that our needs are also very spatially diverse. What are we then supposed to sustain? Or does sustainable development assume that the spatial inequality and patchiness should also remain in perpetuity, and that we are to satisfy the needs locally as they are now?

In some of the definitions of sustainability we see this indeed made explicit. Wimberly (1999) defines that "to be sustainable is to provide for food, fiber, and other natural and social resources needed for the survival of a group – such as a national or international society, an economic sector or residential category – and to provide in a manner that maintains the essential resources for present and future generations." This already implies scales that are other than global, and talks about needs of particular groups on local, regional or national scales. No surprise there are numerous efforts around the world entirely focused on some particular regions, say a city in US - the Sustainable Raleigh project<sup>16</sup>, or a municipality in the Netherlands

14 <http://www.footprintnetwork.org/en/index.php/GFN/page/calculators/>

15 <http://quickfacts.census.gov/qfd/index.html>

16 <http://paradshift.net/2013/08/12/raleigh-nc-agenda-21/>

- "Duurzaam Dalfsen", or a 700 people village in that municipality - "Duurzaam Hoonhorst".

Many other definitions related to sustainability are available. Costanza (1992: 240) emphasized the system's properties, stressing that "sustainability... implies the system's ability to maintain its structure (organization) and function (vigor) over time in the face of external stress (resilience)." Solow (1991) insisted that the system is sustainable as long as the total capital of the system is equal or greater in every next generation. Costanza and Daly (1992) argued that sustainability only occurs when there is no decline in natural capital. Whatever the flavor of the different definitions, there is one common component; all of them talk about maintenance, sustenance, continuity of a certain resource, system, condition and relationship, and in all cases there is the goal of keeping something at a certain level, of avoiding decline.

But how do we marry all these sustainability goals with the ideas of adaptation or evolution, and reconcile the concept of sustainability with such systemic properties as hierarchy and cycling? The renewal cycle has been recognized in many dynamic systems and the cyclic pattern in life histories of complex systems has been often considered as an adaptive mechanism that serves the needs of evolution. According to Costanza and Patten (1995) "evolution cannot occur unless there is limited longevity of the component parts so that new alternatives can be selected". Hegel's dialectic viewed development of systems as a cyclic process of change where negation of a system was a prerequisite of synthesis. Cycles have been observed in numerous systems of very different nature. Describing the renewal cycle, Holling (1986) proposes to look at capital accumulated by the system and notes the cyclic pattern that this variable follows. Starting at low levels, the system gradually accumulates capital, reaching a maximum at the end of the conservation stage, after which the release of capital begins. The cycle starts again after the renewal stage. Gumilev (1990) describes the dynamics of passion, which he views as a driving force for the development of an ethnos in his theory. Similarly, passion grows at first, reaches the acme and then gradually declines as the system turns to homeostasis and then obscurity.

This cyclic nature of development is contrary to the goal of sustainability, which is aimed at preservation, maintenance of a certain state or function. Sustainability in this case is a human intervention that is imposed on a system as part of human activity and is totally controlled and managed by humans in order to preserve the system in a state that is desired. If renewal is an adaptation mechanism, that provides flexibility and potential for change, then sustainability of a system borrows from sustainability of a supra-system and rests on lack of sustainability in subsystems (Voinov & Farley 2007). Therefore increased sustainability of a certain hierarchical level may impede sustainability of larger systems that potentially are even more important in the historical perspective.

So it really looks like the classic definition of sustainability, as something that is maintained and increased, is not operational and we have to think of something different if we want to move towards sustainable development. One of the famous Yogi Berra quotes: "If you don't know where you are going, you might never get there".

My understanding of sustainability is rather related to the social compromise about the size of the human enterprise on planet Earth. Sustainable development is development within these socially accepted limits. This brings us back to the notion of "Limits to Growth". We can easily imagine a sustainable socio-environmental system that would be built on ecological principles, where humans are strictly restricted to their ecological niche, preserving enough living space for other species, conserving natural capital, reusing and recycling resources, so that no or very little additional input is needed. A kind of eco-utopia, or "living with the nature" paradise.

We can also imagine a system that will be entirely driven by technology, where humans occupy all the space they need, all other species are in zoos or farms and are used for the genetic, bio-chemical or digestible material that they can produce. They have no other value per se. Nature is preserved in a couple of microcosms, and every family can buy a ticket to visit one of those for a day or two. Just like going to a museum. The rest is cities, or greenhouses, or mines, or enterprises. With sufficient redundancy built in, probably this system can also be sustainable. A scaled up version of the International Space Station, except with no shuttle rockets coming from outside to refuel and bring food and letters from family.

These are two extremes. Which one do we choose? Or is it going to be something in between? Where in between? The important thing is that there is no one, particular, sustainable socio-environmental system to strive for. There may be many possible solutions. How do we define which one will be the socially accepted and desirable future and how do we transition to it? It remains unclear how to decide about these limits and who decides. Can we perhaps help with our models?

# PARTICIPATORY MODELING

Today it is generally agreed that better decisions are implemented with less conflict and more success, when they engage or even are driven by stakeholders, that is by those who will be bearing the consequences of these decisions. Increasingly there are more requirements for a bottom-up approach where the stakeholders play a role in the knowledge generation and sharing, and, possibly, in the decision making process. The drive toward participatory decision making is primarily fuelled by the increasing realization that the more humans impact the environment and the more they attempt to manage natural resources, the more complex and less predictable the overall socio-ecological system becomes and the harder it becomes to find the right decision and to choose the best management practice (Voinov & Bousquet 2010).

There may be different levels of participation. Sometimes stakeholders can be used only to solicit information, to find the right parameters for our models. Ideally they get involved in the model-building process itself. What is especially valuable, is that in this case the people start to consider the model as their own creation, their 'baby', they are more likely to trust it and to use it. With all the diversity of social and environmental conditions, it is hardly possible to come up with a generalized PM strategy. However some of the basic steps and elements can be identified and are shown in Fig. 6. There are many loops back and forth, and there is no particular order in how the process proceeds. We may need to go back again and again, or we can jump several steps forward if the goals of the study are already achieved and management decisions are agreed upon. While the order is uncertain the major components of the process seem to be quite generic.

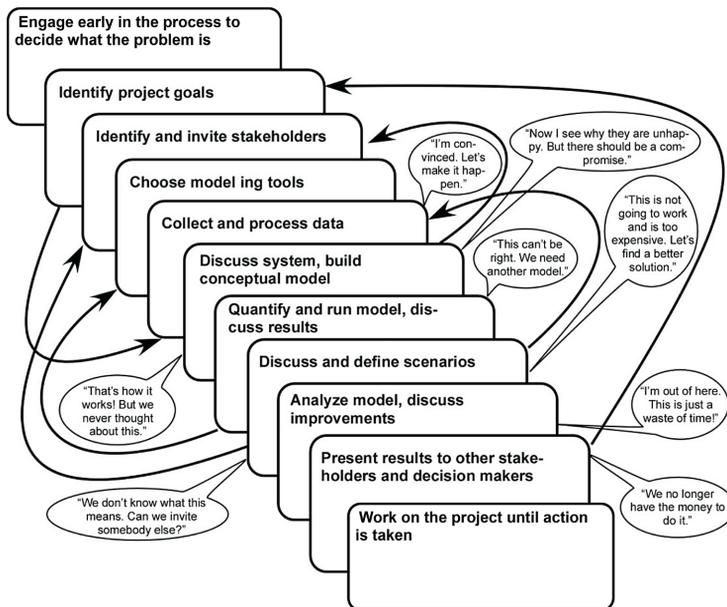


Figure 6. The Participatory Modeling process. Steps are displayed on cards to stress that their order may change depending on stakeholder decisions and preferences.

Participatory modeling may be also seen as a safeguard from the above-mentioned subjectivity in modeling. In fact when the model is thoroughly discussed and documented with various, often times conflicting stakeholders involved, it becomes way harder to bring in assumptions and variables that suit certain purposes, or vested interests. Moreover, stakeholder participation makes the modeling process truly adaptive, so that models can adequately incorporate new information about the systems as it becomes available and adjust to the new goals driven by the decision-making and management needs. The challenges seem to shift into the relational, social dimension of the process that can help us to identify differences and similarities in various case studies, to identify patterns and ways to learn from the experience of the others.

Today several important trends are recognized as developing in the field of participatory modeling. Perhaps the most important are the quantitative and qualitative growth of social media, mobile applications, web services

and other means for broader ‘popular’ access to data and information and for wider social participation in creating these data and information. All this creates more potential for an even broader participation of stakeholders in decision-making processes and further expansion of a new development known as ‘citizen science’. This is what we are exploring together with Frank Ostermann in GIP (Voinov et al. 2016).

If we are to make decisions about our futures, about the extent of the human footprint on this planet, should we perhaps try to involve as many people, stakeholders in the decision process? What kind of tools we need to engage hundreds, or thousands of people in a discussion about our future? Can we just register their ‘likes’ or ‘thumbs ups’ and ‘downs’? Or we can also use social media to better inform stakeholders about the different options, the influences, causations, scenarios, drivers and feedbacks.

Consider for example a toy model that I have once put together to demonstrate how the big corporations (let us call then “Bigs”) interact with smallholders or small and medium sized businesses (“Smalls”) (Voinov 2008). The main difference in how they operate is that there is hardly any competition between the corporations, which manage to divide their spheres of interests without employing the market forces. The small businesses compete with each other and with the corporations. They also try to limit the growth of corporations by legislative means, which is also a non-market mechanism. However corporations also compete with the small businesses for the influence upon the legislators.

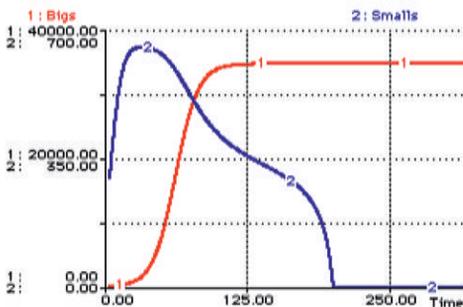


Figure 7. Crash of Smalls if carrying capacity established for Bigs is not small enough.

Since there is an unfair competition between the Bigs and Smalls, the Bigs always win unless there is some restraint added, perhaps a carrying capacity for them that the society imposes on their development. If this parameter is high enough, the Bigs still outcompete the Smalls and eliminate them (Fig.7). However if the parameter is sufficiently low then both actors can persist. How do we decide on the size of this parameter? Could we perhaps post the model on the web, explain the processes and allow the society to play with the system and jointly choose the most appropriate behavior? Can we use the social media to engage the society in making some important decisions about our preferred futures and then to choose the most appropriate pathways to these futures? Imagine there are several sliders that control the model performance, and which are collectively decided by participating individuals. What are the appropriate models that we want to collectively build and run over the Internet to improve our understanding of spatial heterogeneities in preferences and management decisions that can bring us to a sustainable future? This is something I would like to explore with the newly advertised PhD position, which is part of the Geo-data Geniuses investment program of ITC. This research could vastly benefit from closer collaboration with data analytics explored by Raul Zurita-Milla and advanced Network and Agent Based Modeling conducted by Ellen-Wien Augustijn in GIP.

On the downside, we also see that the new opportunities that come from social media still may not immediately translate into better decisions and real actions taken. As observed by Jonathan Swift back in 1710, "it often happens, that if a Lie be believ'd only for an Hour, it has done its Work, and there is no farther occasion for it. Falsehood flies, and the Truth comes limping after it; so that when Men come to be undeceiv'd, it is too late; the Jest is over, and the Tale has had its Effect..."<sup>17</sup> With the Internet, information can really fly around the world in seconds. Unfortunately this applies equally well to misinformation. What makes things even worse is that it is also easy to find like-minded people on the Internet and gain further support to the misinformation spread. This leads to group thinking, which can have a further self-enhancing effect: people are more likely to acquire their knowledge by consulting those who share their values and whom they therefore trust and understand (Kahan 2012). So by the time truth comes out we find that lies have already established their critical mass

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17 1710 November 2 to November 9, The Examiner, Number 15, (Article by Jonathan Swift), Quote Page 2, Column 1, Printed for John Morphew, near Stationers-Hall, London. (Google Books Full View)

of supporters that are now engaged in a positive feedback self-assuring exercise, effectively blocking all the information that would be contradicting the group thinking. Or referring to Hegel's notorious statement that if facts contradict theory, then "um so schlimmer für die Fakten" —so much the worse for the facts<sup>18</sup>. The theory in this case does not have to be anything coming from science. Instead it would be the prevailing beliefs, biases, and preferences of the group, the 'wishful thinking', or perhaps the value choices that promise the most comfort, physical, mental or spiritual.

People are still very dependent on their fast system 1 thinking (Kahneman 2011), primarily based on their intuition, 'gut feeling', preconceived notions, beliefs and biases. This can easily clash with the slow system 2 thinking based on logic, information, knowledge, that which comes from models, data, and analysis. With the new Internet connectivity and the 'information highway' that we now enjoy, we no longer have to rely on our memory to access facts and data, and we could supposedly spend way more resources on processing those facts and information. But can this avalanche of data actually help us in making better decisions and improving our management, or will we be instead overwhelmed by the diversity of information and misinformation that is now available, and instead use this to promote particular vested interests, group ideas? Will we use the abundance of newly available physical and human sensors accessed through the Internet and social media to solve the dire problems of resource crunch (environmental pollution, minerals, energy, space, water, energy - you name it) that we are now facing as a civilization, or will we rather use this information to gain more control for certain groups at the expense of privacy and well-being of other people? This is yet to be seen.

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<sup>18</sup> <http://www.e-flux.com/journal/hegel-and-freud/>

## TO CONCLUDE

I have not pointed out any clear solutions today. But one thing is quite obvious. It is all about values, norms and preferences prevailing in a society, and the corresponding choices we as individuals make. These do change. Consider the tradition of feet binding in China that existed for almost a millennium. It originated among the upper-class court dancers in Imperial China around the 10th century and then spread to the lower classes where it persisted until quite recently, 1950s. The toes of young girls were broken and curled over the sole of the foot. They were then tightly bound and kept that way until the deformation became permanent. So called 'lotus feet' were considered pretty. "The practice of binding feet was not only considered beautiful, it was considered necessary in order to get married and to have a better life."<sup>19</sup> Many young women bound their own feet, while not pressured into doing it by their mothers or family. It was societal pressure. If all the other girls in the village had their feet bound - there was hardly any choice. How is this different from today? If all kids in your class have a smart phone - you really have to have one as well.



Female beauty has and still is a very heterogeneous factor. Kayan women in Myanmar make their necks look longer by wearing brass rings since the age of 5 or even younger, gradually adding the number of rings. The weight of the brass pushes the collarbone down and compresses the rib cage, creating the impression of a longer neck. The rings do hurt<sup>20</sup>, but what wouldn't you do to be beautiful and attractive? Women in the tribe of Mursi in Ethiopia wear plates in their lips, which can be over 12 cm in

<sup>19</sup> <http://www.buzzfeed.com/hayleycampbell/lotus-feet#.nkaxY9PL1y>

<sup>20</sup> <http://hubpages.com/style/Padaung-Neck-Stretchers>

diameter. They stretch their lips and ear lobes and this is also thought to be beautiful<sup>21</sup>. The Suri women in South Sudan pride themselves with the number and size of scars they carry. How much different is this from today's fashion for tattoos and body piercing? And what about breast implants: in US just in one year, 2014, nearly 300,000 women and teenagers underwent surgery to have their breasts enlarged<sup>22</sup>. Now the new fashion on the block: buttock implants and lifts are among the fastest growing procedures. Apparently male plastic surgery rates are also on the rise since 2000<sup>23</sup>. We all like to be beautiful. Except we never know what beautiful will be like in the future. Compare the ideal of female beauty in Rubens's times with what it is now (Fig.8). Spatially it is also very diverse. Beauty in Sub-Saharan Africa resembles Rubens models much more than Victoria's Secret ones.



Figure 8. Above: Peter Paul Rubens, *The Judgement of Paris* (1636–1639). Right: *Victoria Secret models* (2015).

It is quite amazing how generations are being silently manipulated by shaping norms. We are amused or even disgusted by some of the advertisements of the past. But what will our grandkids think of the commercials of today? Or perhaps they might become equally disturbed by the sole notion of advertisement for the sake of increasing our consumption. Because that is exactly what commercials are for: to make you buy things that you do not need, in quantities that exceed your wants. There is a lot of manipulation going on and people are very susceptible to it. Consider how the news shapes what Americans see. Compare two cartograms: one shows the distribution of the world population<sup>24</sup>, the other one is the number of seconds that American cable and network

21 <http://khusela.com/project/faces-omo/>

22 <http://www.ourbodiesourselves.org/health-info/facts-about-breast-implants/>

23 <http://www.plasticsurgery.org/news/2015/plastic-surgery-statistics-show-new-consumer-trends.html>

24 <http://worldmapper.org/index.html#>

news organizations dedicated to news by countries in February 2007<sup>25</sup> (Fig. 9). This happens to be the month when IPCC started to publish its Fourth Assessment Report and released its *Summary for Policymakers* (SPM), which stated that: “Warming of the climate system is unequivocal” and that “Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations”. There was also massive flooding in Indonesia, causing over \$1 Billion in damages and displacing almost half a million people. This was not considered newsworthy. The less educated people are, the less they know, the easier they are to be guided, lured, persuaded to do things that they may not have wanted to do at first.



*Figure 9. Left: A cartogram of the population map of the world. Each country size is proportional to its population. Right: Now the size of the countries is in proportion to the number of seconds that American cable and network news organizations dedicated to news about the respective countries.*

This is where University professors, researchers and teachers have a great responsibility and an important role to play. It is important that we make sure that the results of our research are actually used, that they make a difference, and that action is taken. We have the luxury and ultimate responsibility of access to the bright young minds of future generations, and it is up to us to help them understand the present to be prepared for the future.

<sup>25</sup> [https://www.ted.com/talks/alisa\\_miller\\_shares\\_the\\_news\\_about\\_the\\_news](https://www.ted.com/talks/alisa_miller_shares_the_news_about_the_news)

University of Twente has a great logo: “High Tech, Human Touch”. What is not exactly spelled out is how the two go together. What is the operator between the two? Is it

**High Tech + Human Touch, or  
High Tech x Human Touch, or maybe  
High Tech ^ Human Touch?**

I would go with the third one, except it is not symmetrical. Why not Human Touch ^ High Tech? But certainly not the first one. It is not that we want to do High Tech and then start thinking how to add the Touch. We really want to boost the synergy between the two. Like in participatory modeling. It is not that we are educating stakeholders - it is equally important that the stakeholders are educating us. So let us agree on the HT<sup>2</sup> approach, which means that we are developing technologies that can empower people, but at the same time we are providing these technologies based on what people want, need, understand, know and tell us. The HT<sup>2</sup> approach means that we are not only teaching students but we are constantly learning from them. That is the philosophy of the ATLAS program, which I am now honored to be involved in. This is the philosophy of the Initial MSc that ITC is developing, and which I hope will be successful.

This brings us back to the importance of not just conducting our research, not just properly building our models, testing and running them, but also to the need to deliver our results in compelling and clear ways, developing visualization methods and tools that could motivate people, and perhaps even steer them in the right direction. This is what Menno-Jan Kraak, Corne Elzaker, and Barend Kobben in GIP are researching, and something I find extremely important in the context of modeling interfaces and user interactions. Today we are facing a multibillion advertisement industry and the media that are doing exactly that: finding efficient ways of social manipulation, delivering information and misinformation in such ways that people are making desired decisions, which in most cases have nothing to do with sustainable development or conservation. We should not be afraid to do the same but in reverse, especially since in our case we do not even have to resort to misinformation. The scientific method is about truth; transparency in modeling is another safeguard against misinformation. It becomes only a matter of understanding and presenting this truth in such ways that we can instigate action and empower people to do the right things. As we have it eloquently stated in the UT Vision 2020: “The

University is dedicated to research in order to actually make a difference: to ensure that our findings are used in society, to help to improve the lives of people, and perhaps even to save lives". Building on and integrating the vast experience of geo-spatial information processing in GIP and ITC, developing advanced spatio-temporal modeling tools in search of solutions to the urgent socio-environmental problems of today - this is where I see the role of my chair.

I find even more reasons for hope when looking at the profiles of the new generations to come. According to some polls, the so-called Generation Y, or the Millennials whose birth years range from the early 1980s to the early 2000s, really want to transition to clean energy<sup>26</sup>, they are likely to become the most educated generation in history, they seem to be less concerned with material goods and fame, and more interested in social cohesion, and family values - the human touch that can be very helpful in cases when high technology is not quite there yet. And by the way, nearly half of the Millennials have a tattoo, and one-in-four have a piercing in some place other than an earlobe<sup>27</sup>.

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<sup>26</sup> <http://grist.org/article/millennials-really-want-to-transition-to-clean-energy-says-new-poll/>

<sup>27</sup> <http://www.pewsocialtrends.org/2010/02/24/millennials-confident-connected-open-to-change/>

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It is a pleasure to express my gratitude to a number of people who play important roles in my life.

My first advisor was Yuri Svirezhev, who passed away in 2007. He was a co-advisor on my MSc thesis and then supervised my PhD research. While not always the easiest guy to work with, he had great talent, knowledge and charisma, and taught me a lot about modeling and research. For more than 10 years my boss was Bob Costanza who introduced me to ecological economics and the sustainability thinking. We are still collaborating on several projects and it is always very inspiring to work with him. Josh Farley is my friend and colleague with whom we share so much in how we see things that it is always such a pleasure to discuss all the world problems. Have you noticed that it is always so much nicer to interact with people with whom you already agree?

With Tony Jakeman we have been collaborating since 2000, editing the Environmental Modeling and Software journal. The journal nearly tripled its impact factor over the past 15 years, and Tony's skillful guidance is always a source of inspiration.

I enjoyed my experience working for the US government at the Army Corps of Engineers with Hal Cardwell. The whole AAAS Fellowship experience was exciting and gave me a lot of understanding of how and why governments are not always delivering what they are expected to. Right next came my non-governmental organization experience with Kevin Sellner and Raleigh Hood, running the Chesapeake Community Modeling Program. These were also great times connecting with a lot of people and stakeholders at the interface of science, government and society, while trying to convince them that open source and open science is the way forward. An exercise in herding cats. It also proved to me that still it is the Academia and University environment where I feel myself most fit.

With Anne Van der Veen's gentle persuasion, ITC appeared on my radar screen and then became my home in 2009. My joining ITC almost coincided with the appointment of Tom Veldkamp as the Dean. It was his

dedication, patience and managerial skills that navigated us through the merger with the University of Twente and that now foster all the amazing synergies that we see opening up for ITC as part of a University. It also helps a lot when your research and educational philosophy agrees well with that of your Dean. That is certainly my case with Tom. On the departmental level I find that honesty, transparency and understanding are the main features of Menno-Jan Kraak's leadership. They make the GIP department a very special and pleasant place to work. GIP brings together a huge variety of talents and skills that can really cover the whole workflow from data to knowledge. It is very rewarding when right in your hallway, or just one floor below you can find all the essential skills for all the various transdisciplinary research you choose to pursue. And all that wrapped in a friendly, pleasant and personal attitude. This is how I see GIP today.

My special thanks go to the 10 speakers at the mini-symposium we had today. You are great scholars, colleagues and collaborators, with whom I do hope we can do a lot more in the future. Taking time off your busy schedules to celebrate together with a colleague - this is really precious. Jolanda, you took so good care of every little detail of this event to make sure that all runs smoothly. I am very grateful for that.

I owe very much to my family and friends. Joerg, Caroline, you've been great neighbors - we still miss you. Lyudimila, Jan, our nanny and foster grandparents, your help is much appreciated. My sincere thanks to my in-laws, Lyudmila and Victor, who always come when life is tough and support is needed. This is very kind, thank you. My parents, Zoe and Arkady, unfortunately could not make it to this celebration, but they are always present in my life. It's not just the genes that they gave me. Their love and care are always here for me. My two little bandits, Michael and Timothy, life without you would have been quite empty. I always feel that when your mom takes you away to visit your grandparents. Thank you for the joy and happiness you give, even after a sleepless night you've orchestrated.

Finally, my thanks and hugs to Tatiana, my precious and beloved wife and friend without whom I would not be talking to you today. You're my source of inspiration, and consolation, driver for action, my consultant, accountant, co-author, co-editor, reviewer, adviser, supervisor, cook and housekeeper, and everything else.

Ik heb gezegd.

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