

2019 World Conference on Natural Resource Modelling

**May 22-24, 2019
Montréal, Canada**

Program and abstracts

Program overview

May 22, 2019

	Banque CIBC	Hélène-Desmarais	Marie-Husny
08:00 – 09:00	Registration (Banque CIBC)		
09:00 – 09:15	Welcome Address (Banque CIBC)		
09:15 – 10:15	Plenary 1		
10:15 – 10:45	Coffee Break (Banque CIBC)		
10:45 – 12:15	Case Studies 1	Nominees for Best Ph.D. Student Presentation 1	Viability
12:15 – 14:00	Lunch (Salon L'Oréal)		
14:00 – 16:00	Case Studies 2	Nominees for Best Ph.D. Student Presentation 2	Environment 1
16:00 – 16:30	Coffee Break (Banque CIBC)		
16:30 – 17:45	Tutorial 1		
18:00 – 20:00	Wine and Cheese Party (Salon L'Oréal)		

May 23, 2019

	Banque CIBC	Hélène-Desmarais	Marie-Husny
08:30 – 10:30	Case Studies 3	Nominees for Best Ph.D. Student Presentation 3	Environment 2
10:30 – 11:00	Coffee Break (Banque CIBC)		
11:00 – 12:15	Tutorial 2		
12:15 – 14:00	Lunch (Salon L'Oréal)		
14:00 – 16:00	Methodology 1	Dynamic Games	Multispecies Interactions
19:30 – 22:00	Conference Dinner (ITHQ)		

May 24, 2019

	Banque CIBC	Hélène-Desmarais	Marie-Husny
08:30 – 10:30	Methodology 2	Resilience in the Digital Age	Agriculture Economics
10:30 – 11:00	Coffee Break (Banque CIBC)		
11:00 – 12:00	Plenary 2		
12:00 – 12:30	Closing Session		
12:30 – 14:00	Lunch (Salon L'Oréal)		

Plenary 1

Location: Banque CIBC

Chair: Zaccour, Georges, GERAD - HEC Montréal

09:15 AM Interdisciplinary ocean and fisheries economics with examples from the trenches

Sumaila, Rashid, University of British Columbia

A crucial question still facing humanity is how to successfully manage our interactions with the ocean to ensure long term sustainability both for people everywhere and ocean biodiversity. Here, I explore this question in an interdisciplinary fashion, couched around three key issues, i.e., global warming and climate change; the deployment of public policies such as the provision of fisheries subsidies; and how we manage the high seas. I argue that our ability to manage our oceans successfully depends strongly on enacting policies and taking actions in such a way that positive feedbacks are transmitted between people and nature. The alternative is for negative feedbacks to fester, to the detriment of both.

Case Studies 1

Location: Banque CIBC

Chair: Ay, Jean-Sauveur, INRA

10:45 AM Multi-agent modeling, a lab for building sustainable management policies in coastal and marine ecosystems. The case of the Golfe du Lion Marine Park, results from the SAFRAN project

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We modeled the Marine Park as a socio-ecological system and developed scenarios to 2050, inviting various stakeholders to build them. We considered mainly artificial reefs and offshore wind turbines facilities, phytoplankton variation and access and use rights as variables of sustainable management policies. The modeling approach is agent-based for looking at the evolution of supporting and regulating, recreational and provisioning services. Rocky and coral reefs, sands and posidonia habitats are placed at its core, specifying for each of them the trophic chain. Implementing scenarios revealed that access and use rights are the determining factors in the evolution of ecosystem services.

11:15 AM Verification of GEM data in Iran using synoptic stations' temperature and precipitation data

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The Global Environmental Multiscale Model (GEM) is an integrated forecasting and data assimilation system developed by Environment and Climate Change Canada. It is the operational model at the Canadian Meteorological Centre for weather forecasting. The model is currently operational for the global 25 km data assimilation cycle and medium-range forecasting, the regional 10 km data assimilation cycle and short-range forecasting over North America, and the high-resolution 2.5 km data assimilation cycle and short-range forecasting over Canada. In this research, the performance of the global forecast outputs were evaluated for the whole country of Iran (1,648,000 km²). Temperature and precipitation data generated by the global-scale GEM model are evaluated with 177 synoptic stations data in daily, monthly and yearly scale. The primary results using 7 synoptic stations located in Sefidrud River Basin (the second largest river in Iran with more than 60,000 km² area) show that the GEM model performance has acceptable accuracy regarding rainfall and temperature. However, temperature data have a much better agreement with the observations than precipitation in the region.

11:45 AM Disease dispersion as a spatial interaction: the case of grapevine flavescence dorée

Ay, Jean-Sauveur, INRA, jsay@inra.fr

Flavescence dorée is a severe vector-borne grapevine disease triggering quick death of the vine stock. It is transmitted exclusively by a leafhopper and has spread throughout France where it has become a serious issue (presently, it is a concern for more than half of French vineyards). Focusing on the spatial dissemination of FD, this paper investigates the private control and land-use strategies of heterogeneous landowners, and their socially optimal counterparts. The theoretical model of individual decisions take into account strategic interactions among neighbors, as treatment and land use choices have consequences beyond a landowner's plot. Using small-scale data of contamination and of mandatory pesticide application, the probability of being infected by FD is derived with a spatial econometrics specification.

Nominees for Best Ph.D. Student Presentation 1

Location: Hélène-Desmarais

Chair: Henson, Shandelle, Andrews University

10:45 AM How to improve ecological-economic resilience of a fished coral reef through stochastic MMSY?

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Ahad-Cisse, Abdoul, University of Cayenne

This paper investigates the ecological-economic resilience of coral reef ecosystems under fishing and environmental pressures. To achieve this, a dynamic, spatially explicit, multi-species, multi-fleet model is developed and calibrated using ecological, economic and environmental data in French Polynesia. Stochastic environmental shocks assumed to negatively impact coral cover and consequently the entire coral reef socio-ecosystem. Four exploratory and a MMSY (Multi-Species Maximum Sustainable Yield) fishing management strategies are compared in terms of ecological-economic outcomes and resilience. The MMSY appears as the more sustainable economic and ecological strategy that promotes resilience. As a consequence, adaptive and stochastic strategies seem to perform better.

11:15 AM Evaluating solar photovoltaic potential across various landscapes with LiDAR and Imagery Analysis: case study Atlantic County, New Jersey, USA

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We model potential for solar photovoltaic technology adoption across several land use classifications using spatial analysis and remote sensing techniques. Solar photovoltaics are an important part of the clean energy future and can be installed across a wide range of environments. We identify optimal locations for deployment based on system design optimization, levelized cost of energy, and conservation of agriculture and open spaces. Quantifying potential for renewable energy technology in this way supports clean energy policy development with considerations of natural resource conservation.

11:45 AM Spatial spillover effects of environmental pollution in China's central plains urban agglomeration

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Promoting the rise of Central China is one of the most important national strategies regarding the promotion of China's economic development. However, the environmental issues in the central regions have become remarkably severe. It is therefore worthwhile exploring how economic development and environmental protection can be coordinated. Focusing on the 29 prefecture-level cities in the Central Plains Urban Agglomeration, the authors empirically analyze the relationship

between the economy and the environment from 2004 to 2014. The combined methods of the spatial autocorrelation model, the environmental Kuznets curve, and the global spatial correlation test are systematically employed. The results show that: (1) a strong spatial correlation exists between industrial wastewater discharge, industrial sulfur dioxide, and dust emissions in the Central Plains Urban Agglomeration; (2) the relationship between the economy and the environment of this urban agglomeration reveals an inverted “U” curve, which confirms the classical environmental Kuznets curve hypothesis. Industrial dust emissions have surpassed the inflection point of the Kuznets curve, but its spatial spillover effect still remains strong. This is caused by an accumulation effect and a lag effect; (3) the proportion of the secondary industry and population has a strong positive effect on pollution discharge; investments in science and technology have a certain inhibitory effect on industrial sulfur dioxide emission. Moreover, an increase in the number of industrial enterprises has a negative effect on industrial wastewater emission. At the end, the authors put forward policy recommendations regarding the establishment of a joint supervisory department and unified environmental standards at the regional level to deal with the spillover effects of pollution.

Viability

Location: Marie-Husny

Chair: Durand, Marie-Hélène, IRD

10:45 AM **Mitigation of ecological economic vulnerabilities with adaptive controls**

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Ecosystems and socio-ecosystems including fisheries have to face many ecological and economic uncertainties, vulnerabilities and risks. In this paper, a stochastic viability approach is proposed as operational framework for an adaptive decision-making mitigating these ecological economic vulnerabilities. An ecoviability scenario balancing ecological and economic objective is proposed. Two different strategies are compared: non-adaptive control (open loop) and adaptive control (closed loop or feedback control). The general framework is applied to the case of Bay of Biscay mixed fisheries. We show the gains of adaptive control approach both in term of spawning stock biomass, profits of fleets and ecoviability probability.

11:15 AM **Modelling the viability of livestock systems with target: the case of the French West Indies**

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This article aims to analyze farmers strategic decisions in a context of persistent pollutant formerly used in banana farming systems in the French West Indies. We wonder to what extent the adaptive capacity of livestock farming systems are viable. A theoretical viability model allows to identify the decision rules to be followed by the stakeholders of the livestock sector. Our results depict the diversity of rearing strategies according to the means, costs and duration of animal decontamination. It thus helps to define scenarios that are economically viable and socially acceptable considering a tighten regulation (decrease of the Maximum Residue Limit).

11:45 AM

The temporal dynamics of ecosystem services and their valuation: the case of agricultural soil quality

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Valuation of natural capital and of services provided by the ecosystems, is done by accounting technics or cost-benefit analysis and used as management tool aimed at conservation. The spatial dynamics are taken into account by assessments of land use changes but the temporal dynamics are rarely considered. However, the value of ecosystem services varies depending on initial state of the ecosystem whose functions can be more or less degraded and for which time and cost of restoration or reproduction differ. Using a viability model of agricultural soil fertility management, we show that the relationship between the value of the ecosystem service provided by the soil quality (estimated by the best economic performance) and the time of restoration is not linear.

Case Studies 2

Location: Banque CIBC
Chair: Bahn, Olivier, HEC Montréal

02:00 PM

GIS-based assessment of potential bioenergy feedstock supply using fuzzy logic and network optimization

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We propose a two-phase methodology integrating fuzzy logic and network optimization to assess potential bioenergy supply. The fuzzy analysis uses multiple criteria, including meteorological conditions, soil texture and topography to identify suitable cultivating regions. The network location analysis uses real road network, existing biorefineries to evaluate feedstock accessibility based on potential crop yield and cost of transportation for existing biorefineries for the supply of biomass. We assess the magnitude of land use changes and estimate the potential biomass supply from various land uses. We apply the concept of assessing the potential for switchgrass-based bioenergy in Missouri as a case study

02:30 PM

Modeling urban palm populations to estimate potential losses from coconut rhinoceros beetle (*Oryctes rhinoceros*)

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The coconut rhinoceros beetle, native to southern Asia, was recently discovered in Hawaii. If it invaded the U.S. mainland, this insect could devastate urban palms. We used street tree inventory data to model palm populations in U.S. municipal forests. We applied stochastic gradient boosting to model palm relative abundance in street tree populations based on environmental and geographic variables. We then modeled overall street tree density as a function of biogeographic region and palm relative abundance. We combined the models to estimate total street palm populations. These estimates facilitate evaluation of the potential costs associated with a major palm-killing pest.

03:00 PM

An age-structured population model for lates calcarifer

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The Australian Lates Calcarifer (Barramundi) fish species forms the basis of important commercial, recreational and customary Indigenous fisheries in Queensland. The development of quantitative models for this iconic Australian fish has been challenged by the complex nature of its life-cycle and the influence of environmental factors on key biological processes. Further complication includes the

effects of stocked Barramundi fingerlings that contribute to the wild-caught fishery in events of severe flooding. In this work, an age-structure population model describing Barramundi's unique characteristics and discussing extensions to address external influence factors is being presented. It is assumed, that the recruitment follows the non-linear Beverton-Holt equation, modified by a variation factor to account for environmental variations. As is often considered in fishery sciences, it is further assumed that the Schaefer assumption holds. That is, catch is proportional to effort and abundance. In a collaborative project between the Department of Agriculture and Fisheries Queensland and the Centre for Applications in Natural Resource Mathematics, we applied this developed mathematical model to collected fisheries data. Using a Bayesian approach, the mathematical model was calibrated to assess the Barramundi stock and a scenario analysis was performed to explore the stability of the obtained results.

03:30 PM The Canadian contribution to limiting global warming below 2 degree C: insights from a TIMES approach

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Canada committed to reduce its greenhouse gas (GHG) emissions by 30% below 2005 levels, by 2030, and by 70% to 90% below 2005 levels, by 2050. These challenging commitments require special consideration of the energy sector. This presentation identifies different decarbonization pathways that would allow Canada to participate in global mitigation efforts. We analyze four GHG mitigation scenarios with increasing levels of mitigation efforts using NATEM, a TIMES model for Canada. The main transformations in the energy system include significant energy conservation and efficiency improvements, greater penetration of electricity in end-use sectors, and an increased use of bioenergy.

Nominees for Best Ph.D. Student Presentation 2

Location: Hélène-Desmarais
Chair: Van Langevelde, Frank, Wageningen University

02:00 PM Information structures and environmental agreements

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We consider international agreements for the protection of the environment where the signatories agree to cooperate in order to determine the level of their joint emissions. In a stylized model, we evaluate the impact of two information structures on the stability of an International Environmental Agreement (IEA) over time. We, first, analyze the impact of signatories' leadership on the steady-state pollution stock and the corresponding size of the internally and externally stable coalition. We, then, consider the impact of taking into consideration the pollution stock dynamics and the evolution of the coalition size by all players in the decision making process as well as in the corresponding steady-state values.

02:30 PM Self enforcing environmental agreements, taxes and delayed information in a continuous time Fish Wars model

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In this paper, we analyse a continuous time version of Fish Wars with the infinite time horizon and state-dependent constraints on controls. We calculate the social optimum and a Nash equilibrium which always leads to the depletion of the resource even if the social optimum results in the sustainability. We propose two ways of solving the problems of enforcing optimality: either by a tax-subsidy system or by an environmental agreement even if we assume that it takes time to detect any defection of a player. We also propose a general algorithm of finding financial incentives enforcing the optimal profile in a large class of differential games.

03:00 PM Ecosystem dynamics and fishing management scenarios for the coastal fishery in French Guiana

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We apply an ecosystem-based fishery management approach on the small-scale fishery of French Guiana. To achieve this, we rely on a multi-species, multi-fleet model inspired by Ecosim. The model is calibrated using data (provided by IFREMER) of fishing landings and efforts from 2006 to 2017 for 13 species and 4 fleets. The calibration exhibits the importance of illegal fishing (Suriman, Brazil) in the ecosystem dynamic. From the calibrated model, we contrast different fishing management scenarios at the horizon 2050 including a status quo scenario and closure scenario.

03:30 PM Recycling under environmental, climate and resource constraints

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We study the recycling opportunity of an industrial sector constrained by climate, resource and waste capacities. A final good is produced from virgin and recycled materials, and its consumption releases waste and GHG emissions. We identify the optimal trajectories of resources use, mainly depending on the emission rates of each resource and by the relative scarcity of their stocks. Recycling is sometimes an opportunity to reduce the impact of consumption on primary resources and waste but can still affect the environment. Last, we show that the emissions ceiling and recovery rates are complementary to improve the environmental efficiency.

Environment 1

Location: Marie-Husny
Chair: Rubio, Santiago J., University of Valencia

02:00 PM The inefficiency of the centralized economy with a pollution externality under non-constant discounting

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We analyze an endogenous growth model with non-constant discounting and a pollution externality affecting utility. With a decreasing rate of impatience time-consistent agents anticipate the behavior of their future selves and play a game against them. The strategic interaction between subsequent central planners implies slower growth than the market solution, where the pollution externality is not internalized. Indeed it can be too slow from a social welfare standpoint. Contrary to exponential discounting, for any non-constant discount function we prove that the market equilibrium is Pareto-improving provided that the pollution externality is sufficiently small.

02:30 PM International environmental cooperation and dynamic stock effects

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Many key environmental concerns today involve strategic interactions among sovereign countries. While most transboundary pollution problems involve stock pollutants, much of the literature on international environmental agreements (IEAs) uses static models. Such models ignore the fact that changes in the stock of pollution may affect the incentives of countries to join an IEA. In this paper we analyze effect of pollutant stock dynamics on IEA membership assuming that at any time period each country makes a decision whether to participate in an IEA or not, and depending on the outcome on these decisions, each country adjusts its emission policy according to the feedback Nash equilibrium. Our objective is to find equilibrium size of an IEA, which withstands possible one-shot deviations. Numerical analysis allows us to conclude that the number of countries exposed to pollution changes the qualitative results from the previous literature about the size of the stable IEA. Our findings suggest that smaller, perhaps, local or regional, agreements may have higher chances for success than global agreements in terms of share of participating countries. Pollution stock can either increase or decrease, depending on total number of involved countries and their characteristics. Additionally,

initial level of the stock makes a difference, and if it is too high, it leads to a lower number of signatories in the steady state. Our results demonstrate that free-riding incentives increase if the stock of pollution goes up, especially if total number of the countries is very large.

03:00 PM **When does eco-efficiency rebounds or backfires? an analytical model**

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It is known that an eco-efficiency strategy, which save resources in the production process, may be offset by a rebound effect; it may even backfire. Less known are the exact conditions under which eco-efficiency rebounds or backfires. This article fills the gap by providing an analytical model of the rebound and backfire effects. We propose an optimal control framework of dynamic pricing and eco-efficiency investment, for which eco-efficiency reduces the unit production cost and boosts the demand of green consumers. Results, which hold with general demand formulations, examine the analytic conditions for the rebound and backfire effects. They also highlight the possibility of a reverse rebound effect. Such results pave the way to sounder green economic strategies.

03:30 PM **Self-enforcing international environmental agreements: adaptation and complementarity**

Rubio, Santiago J., University of Valencia, santiago.rubio@uv.es

This paper studies the impact of adaptation on the stability of an international emission agreement. To address this issue we solve a three-stage coalition formation game where in the first stage countries decide whether or not to sign the agreement. Then, in the second stage, signatories (playing together) and non-signatories (playing individually) select their levels of emissions. Finally, in the third stage, each country decides on its level of adaptation noncooperatively. We solve this game for two models. For both, it is assumed that damages are linear with respect to emissions which guarantees that emissions are strategic complements in the second stage of the game. However, for the first model adaptation reduces the marginal damages of emissions in a multiplicative way whereas for the second model the reduction occurs in an additive way. Our analysis shows that the models yield different predictions in terms of participation. In the first case, we find that the larger the gains of full cooperation, the larger the cooperation. However, in the second case, the unique stable agreement we find consists of three countries regardless of the gains of full cooperation. These results suggest that complementarity can play in favor of cooperation but that it is not a sufficient condition to obtain more participation in an emission agreement. Finally, we would like to point out that our research indicates that the way adaptation reduces damages plays a critical role over the outcome of the coalition formation game.

Tutorial 1

Location: Banque CIBC

Chair: Zaccour, Georges, GERAD - HEC Montréal

04:30 PM **Extreme value analysis of environmental time-series: a primer**

Dupuis, Debbie, GERAD - HEC Montréal, debbie.dupuis@hec.ca

The sustainability of human activities depends critically on environmental and resource-based factors. Rising pressure on the natural environment is progressively challenging viability. Heat waves are becoming more common, rainfall is intensifying, and droughts and major windstorms are perceived to be increasing in frequency. Forecasting the likely size and impacts of such events is essential for adaptation and mitigation. In response to this exigency, the statistical modeling of complex extreme events has evolved rapidly over the past decade. In this tutorial, we will review the basic ideas behind classical extreme value analysis and show how recent advances shed light on important changes in environmental extremes.

Case Studies 3

Location: Banque CIBC

Chair: Streipert, Sabrina, University of Queensland

08:30 AM Do heterogeneous tourists and residents value differently coastal erosion management? Evidence from Hoian (Vietnam), a UNESCO World Heritage Site

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The paper provides an in-depth comparison between tourists' and residents' preferences towards coastal erosion management programs. The paper applies Generalized Multinomial Model with all correlated terms between random parameters to account for both taste heterogeneity and scale heterogeneity of respondents. The paper finds similar preference for a wider and more public beach but different inclination to facilities and protection structures between two groups. The results show a strong taste and scale heterogeneity across respondents. Households' choices are more difficult to predict than tourists due to complexity of choice set, poor definition of choice card and unfamiliarity of survey towards household. High scale heterogeneity also reflects random and lexicographic respondents in group of households.

09:00 AM Coastal dynamics and adaptation to uncertain sea level rise: optimal portfolios for salt marsh migration

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The sustainability of dynamic natural systems often depends on their capacity to adapt to uncertain climate-related changes, where different management options may be combined to facilitate this adaptation. Salt marshes exemplify such a system. Marsh sustainability under rapid sea level rise requires the preservation of transgression zones - undeveloped uplands onto which marshes migrate. Whether these uplands eventually become marsh depends on uncertain sea level rise and natural dynamics that determine migration onto different land types. Under conditions such as these, systematically diversified management actions likely outperform ad hoc or non-diversified alternatives. This paper develops the first adaptation portfolio model designed to optimize the benefits of a migrating coastal resource. Results are illustrated using a case study of marsh conservation in Virginia, USA. Results suggest that models of this type can enhance adaptation benefits beyond those available via current approaches.

09:30 AM Snowfall pattern and its impact on snow resources in Kunes Valley of Tianshan Mountains, China

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Snow resource from snowfall is a key source contributing to water resources in arid region. Better understanding snowfall pattern and its impact on snow resource can improve water resources management. Based on the monitoring data of snowfall and snowpack, this study integrated the weather, snowfall and snowpack to analyze snowfall pattern and snow resource in the study area. The results showed that snowfall mainly takes place from October to April in next year. Since the study area has the continental snow climate, the snow resource is characterized by low density, low shear strength and high proportion of raw frost.

10:00 AM Intermittent electric generation technologies and smart meters: substitutes or complements?

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We model a simplified electric market with producers using either conventional or intermittent electric generators and consumers equipped with either smart or traditional meters. We calculate the investment in intermittent technologies and smart meters in a social optimum. We find that the optimal penetration of smart meters is increasing in the volatility of the electric spot price. As a consequence, intermittent capacities and smart-meters are complement, only if the correlation existing between intermittent energy and demand is negative or if the capacity of intermittent generators is large enough. Otherwise, larger intermittent capacities actually help to decrease the volatility of the electric spot price, making smart-meters less useful. We also give a numerical application, calibrated to represent the French electric market in 2016 and policy objective for 2030. We show in particular that a general adoption of smart meters would be optimal only if the cost of installing and operating smart meters was unrealistically low.

Nominees for Best Ph.D. Student Presentation 3

Location: Hélène-Desmarais
Chair: Trijoulet, Vanessa, DTU Technical University of Denmark

08:30 AM Optimizing stocking and harvesting strategy for aquaculture

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Liu, Yajie, yajie.liu@uit.no

This paper is about to examine the optimal management strategy of salmon aquaculture by incorporating a sequential stocking and harvesting schedule. The focus of the paper is on the salmon grow-out stage – the rearing and feeding of salmon smolt in sea cages to market size. The salmon production is determined by the growth of salmon which is defined by varying biophysical factors such as seasonal changes (e.g., temperature), operational decision (e.g., delousing) and feeding while the profitability is affected by variables associated with production cost, management strategies and market price. By taking into account these dimensions, i.e., fish physiology and economics of production, we develop a bioeconomic model to analyse a sequential stocking and harvesting schedule. Dynamic programming is used to determine the stocking and harvesting strategies to maximize the overall productivity and profitability of the salmon grow-out stage. The preliminary result indicates that a sequential stocking and harvesting schedule generate a higher total profit than a single stocking and harvesting schedule, but dependent on stocking and harvesting strategies.

09:00 AM Estimating the economic damages of United States invasive forest pests

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Urban trees are the main target of economic damages due to invasive forest pests in the United States. Existing damage estimates due to pest species are highly cited (263 citations) and used in policy recommendations (ISPM15), but are currently out of date. We combined three existing frameworks to more accurately estimate future damages to US urban trees due to invasive forest pests by building off of an existing economic approach to estimate pest damages (Aukema et al. 2011), a recent modelling framework for US urban tree distributions (Koch et al. 2018), as well as forecasts of all-species forest pest spread.

09:30 AM Viability of agro-ecological systems under climatic uncertainty

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In order to cope with the post-war demographic boom and ensure food security, agronomic systems drastically changed and migrated to agricultural practices based on chemical fertilization of soil and intensive and specialized farming practices. This has increased soil productivity in the short term, but in the long term have caused serious ecological drawbacks (soil degradation, pollution, loss of biodiversity, erosion, etc.) and even reversed the trend of the agricultural productivity. It is therefore necessary to think about some ways to limit these damages while ensuring an acceptable agricultural yield. In this work we rely on the mathematical viability theory to study the sustainability of agricultural systems subject to climate uncertainty. Our objective is to determine farming practices and activity sequences that allow to restore soil quality to a desired level while ensuring an acceptable level of productivity in the presence of risk of major climatic disasters.

10:00 AM Stochastic and stratified dispersal and their effect on predicting invasive pest populations: a case of Emerald Ash Borer (EAB) in New Jersey

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The advent of globalized trade has led to the introduction of invasive pests and diseases. The dispersal rate of pests and disease has an intrinsic impact on the intensity of these disturbances. Many pests exhibit irregular spread due not only to unknown biological factors, but also due to anthropogenic transport. EAB is an Asiatic pest that has been spreading across the United States since the late 1990s and has since eliminated approximately 85 million ash trees. We propose a stochastic spread and consumption model to address the issue. The goal is the capture of spread caused by natural and anthropogenic means.

Environment 2

Location: Marie-Husny

Chair: Martín-Herrán, Guiomar, IMUVA, Universidad de Valladolid

08:30 AM On optimal extraction under asymmetric information over reclamation costs

Lappi, Pauli, Ca' Foscari University of Venice and CMCC, pauli.lappi@helsinki.fi

Exhaustible resource extraction ends with costly reclamation and producers have better information about future reclamation costs than the regulator. This paper analyzes the second-best optimal reclamation contract between the firm and the regulator, the optimal pollution tax and the shut-down date in a two-stage model, in which extraction is followed by costly reclamation. It is shown, among other things, that asymmetric information regarding the costs affects the optimal pollution tax and the shut-down date, but the tax and the date are nevertheless identical across different firm types. Optimal tax can be lower or higher than the tax under complete information.

09:00 AM Cooperation with asymmetric environmental valuation and responsibility in a dynamic setting

Cabo, Francisco, Universidad de Valladolid, pcabo@eco.uva.es

Tidball, Mabel, INRA, CEE-M, mabel.tidball@inra.fr

When an environmental agreement between two countries is regarded from a dynamic perspective, very often cooperation does not imply an immediate reward. More to the contrary, an agreement to reduce the emissions of pollutants is usually associated with lower flows of production income. However in a profitable agreement the current costs are more than compensated by a future cleaner environment. While this is true globally (for the two countries), neither the costs from lower emissions nor the value of a cleaner environment need to be identical for the two parts. Because the uneven benefits from cooperation are delayed, it is the cost of compliance what needs to be distributed between the signing countries. This paper analyzes a sharing mechanism satisfying two main

properties. First, a benefit-pay-principle: the greater the benefit from cooperation the greater the share of the costs. And secondly, assuming that the responsibility from the initial environmental problem is not even across countries, a polluter's pay principle axiom requires that a country's share of the costs increases with its responsibility. Moreover, the sharing scheme must be defined to guarantee time consistency. At any intermediate instant of time, no country can do better by deviating from cooperation with the sharing mechanism presented in the paper.

09:30 AM Valuing joint environmental amenities with an irreversible investment

Cairns, Robert, McGill University, robert.cairns@mcgill.ca

Pommeret, Aude, Universite Savoie-Mont Blanc, aude.pommeret@univ-smb.fr

We consider a forward-looking method of evaluating or accounting for an environmental resource that can be converted into another type of asset at a forward time to be chosen by an economic agent. The accounting is done, with utility as numeraire and with money as numeraire, first under certainty and then under uncertainty using the theory of investment under uncertainty. Since timing of the conversion is the source of capital gains and the potential for capital gains affects decisions, the capital gains should be accounted.

10:00 AM On implementation of efficiency-inducing taxation for polluting oligopolists

Rubio, Santiago J., University of Valencia, santiago.rubio@uv.es

Martín-Herrán, Guiomar, Universidad de Valladolid, guiomar@eco.uva.es

Benchekroun and Long (1998, JPubE) show that there exists a time-independent tax rule that guides polluting oligopolists to achieve the socially optimum production path. In their paper, a regulation classical approach is followed assuming implicitly a benevolent dictatorship that announces at the initial period the per unit tax rule that is applicable to all firms, at all time. Then, the coefficients of the tax rule are calculated by equalization of the first order conditions that characterize the efficient solution with the first order condition that characterize the regulated market equilibrium. In this paper we address the issue of the implementation of the efficient outcome adopting a strategic approach where the environmental regulator is a player of a policy game. In the first part of the paper, we show that the stagewise feedback Stackelberg equilibrium where the regulator is the leader of the game implements the efficient outcome and that this equilibrium is temporally consistent. Thus, the classical approach and the strategic approach yields the same tax rule provided that the regulator acts as the leader of the game. In the second part of the paper, we compute the global feedback Stackelberg equilibrium and show that not only this equilibrium does not implement the efficient outcome but also that is temporally inconsistent.

Tutorial 2

Location: Banque CIBC

Chair: Breton, Michèle, GERAD - HEC Montréal

11:00 AM Enlisting Poincaré to save the world: geometry and the economic impact of ecological systems with tipping points

Wagener, Florian, University of Amsterdam, f.o.o.wagener@uva.nl

Environmental interest conflicts, like climate change, connect physical and social dynamics. Positive feedback loops in the physical dynamics can be triggered by passing tipping points. The associated models are typically non-linear and it is impossible to even solve the optimal management problem analytically. Fortunately geometrical methods that go back to Poincaré can come to the rescue. They delineate in which situations the manager, instead of fine-tuning a single basic type of policy, has to make fundamentally different choices. The methods can be extended to dynamic environmental interest conflicts between several parties.

Methodology 1

Location: Banque CIBC

Chair: De Lara, Michel, Université Paris-Est

02:00 PM **Optimal harvesting of a regime-switching stochastic growing renewable resource: a utility theory approach**

Sadefo Kamdem, Jules, Université de Guyane (DFR SJE), jules.sadefo@univ-guyane.fr

In this paper, following Smith (1978) and Ludwig (1979), we examine the optimal rate of extraction from a stochastically regime-switching growing resource stock (typically to maximize the expected flow of utility from net revenue). Assuming a continuous-time stochastic regime switching for the biomass Gilpin-Ayala growth function, and CRRA utility function for firms preferences, we find the optimal extraction rate that maximizes the expected integral of the utility function of net revenue of firms.

02:30 PM **Probability of misidentifying population declines and recoveries using linear models**

Filar, Jerzy, University of Queensland, j.filar@uq.edu.au

Holden, Matthew, University of Queensland, m.holden1@uq.edu.au

Accurately estimating trends in population abundance is critical for developing ecological theory, performing environmental assessments, and advising natural resource management. While the error and power of statistical methods for detecting population declines and recoveries are well studied, they rarely consider the issue of density dependence. If population size time series data occurs in an area where the species is abundant, density dependence may cause the over-prediction of a population decline. In this paper, we provide simple analytic formulae for the probability of misestimating population growth rates above or below a specified threshold. We then use the formulae in two applied contexts (1) the probability of falsely predicting a threatened species is declining or recovering and (2) the use of linear population models for predicting species occurrence. In the latter case, we derive simple rules of thumb for the critical population abundance, in relation to carrying capacity, after which density dependence interferes with accurate predictions of persistence. The critical abundance can be used as a guideline for when it may be appropriate to use linear population process models to predict species occurrence in a density-dependent world.

03:00 PM **Risk measures for natural resources management strategy assessment**

De Lara, Michel, Université Paris-Est, delara@cermics.enpc.fr

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Quaas, Martin, Leipzig University, martin.quaas@idiv.de

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Strategy assessment is part of natural resources management. Uncertainty is ever present, as ecosystem functioning is often poorly understood and modeled, often depends upon variable environmental conditions, and as a time spans can extend over decades. We propose to introduce risk measures, originally designed for mathematical finance, in strategy assessment for natural resources management. In a first part, we set the mathematical framework for natural resources management, and outline the traditional methods of strategy assessment in this framework. Then, we introduce a novel approach based on risk measures. The second part is a case study of selective fishery of Baltic cod (*Gadus morhua*). We compare the strategies evaluated as "sustainable" according to the novel approach and to the traditional approaches, with numerical simulations. In the third part, we open perspectives and propose theoretical issues left to explore.

Dynamic Games

Location: H el ene-Desmarais

Chair: Joosten, Reinoud, University of Twente

02:00 PM **A discrete time LQ Stackelberg game modelling fishing in presence of a poacher**

Wiszniewska-Matyszkiel, Agnieszka, Institute of Applied Mathematics and Mechanics, Warsaw University, agnese@mimuw.edu.pl

Singh, Rajani, University of Warsaw, r.singh@mimuw.edu.pl

We analyse the simplest linear quadratic Stackelberg dynamic game of extraction of a fishery by two players: a far-sighted Owner of the lake and a myopic Poacher. Obviously, the interpretation of the game implies that there are linear state-dependent constraints on players' decisions. Besides of being far-sighted, the Owner is the Stackelberg leader. We consider the feedback information structure of both players, while the Poacher also knows the current decision of the Owner, who is the first mover. If the game is one stage only, the informational advantage of the Owner, results in the fact that his catch and payoff are larger than the Poacher's. If the game has two stages, the far-sightedness of the Leader becomes costly---for certain levels of the initial biomass of fish, his first-stage catch, payoff and value function are substantially lower than Poacher's. Besides, the equilibrium strategies are discontinuous for both players and the Owner's optimal strategy is nonunique, although the value function of the Owner is continuous and unique. Moreover, the value function of the Owner is not monotone in the initial biomass of fish even in one stage. By this example, we illustrate difficulties which appear in calculation of Stackelberg equilibria in presence of constraints which may be active at the optimum. We also compare these myopic-follower-Stackelberg equilibria to the symmetric Nash equilibria in the same game.

02:30 PM **Optimal and Markov-perfect Nash equilibria in harvesting age-structured populations**

Quaas, Martin, Leipzig University, martin.quaas@idiv.de

Tahvonen, Olli, University of Helsinki, Department of Economics, Department of Forest Sciences, olli.tahvonen@helsinki.fi

We specify an analytically solvable age-structured harvesting model for collectively optimal and Markov-perfect Nash equilibria in both deterministic and stochastic settings. The model has any number of age-classes and is assumed to be harvested from one or two age classes. The collectively optimal harvests are obtained in closed form as functions of the number of individuals in the given age class. The existence of sustainable solutions is shown to depend on fundamental biological factors and rate of discount in addition to the internal delays in the age-structured system. In a symmetric game all actors harvest both age classes and the existence of sustainable Nash equilibrium depends on the objective functional properties besides the rate of discount. In an asymmetric game, the sustainability depends on how the number of actors are divided into groups harvesting population age classes in different locations. The collectively optimal and Nash equilibria are shown to be globally asymptotically stable for optimal feedback solutions. Stochastic recruitment makes harvesting more conservative in both the optimal solution and various Nash equilibria.

03:00 PM **A model of river pollution as a dynamic game with network externalities**

Sedakov, Artem, Saint Petersburg State University, a.sedakov@spbu.ru

Qiao, Han, School of Economics and Management, University of Chinese Academy of Sciences

Wang, Shouyang, Academy of Mathematics and Systems Science, Chinese Academy of Sciences

In network games, a network is an important attribute of players' strategies: each player adopts her behavior not only by taking into account standard information about her opponents such as objectives, game dynamics, and information structure; but she also evaluates the communication structure of players represented by the network. We investigate a dynamic game with network externalities in which a state variable of each player is influenced by her own decision and the decisions of her predecessors in the network. For the game under consideration, we identify Nash equilibrium and cooperative behavior. Next, we use our findings to take in the important environmental problem of river pollution. We analyze this model in detail by incorporating a firm's location and analytically comparing equilibrium and cooperative behavior.

03:30 PM

Strong rarity value in view of hysteresis in an ETP-ESP fishery game model

Joosten, Reinoud, University of Twente, r.a.m.g.joosten@utwente.nl

ETP-ESP are stochastic games with endogenous transition probabilities and endogenous state payoffs, i.e., depend on the action choices made by the players in the past. These stochastic games developed from games with frequency dependent stage payoffs in a series of generalizations inspired by efforts to model replenishable resource extraction games such as fishery games. Strong rarity value in a fishery is a phenomenon in which an increase in scarcity or rarity of a species, and the subsequent decrease in landing sizes, is more than compensated by price effects for the exploiters of the resource. Simply stated, despite decreasing catches and increasing search costs the profits of the agents (continue to) grow if the resource is sufficiently scarce. Rarity value is well documented in the context of managing endangered species where it is seen as a major if not fatal threat to the survival of the species at hand. A real world candidate of this phenomenon if fisheries might be bluefin tuna. Hysteresis in the same context can be seen as a regime shift in which overfishing moves the system into a stable low resource-level state after some time, but it takes a surprising amount of time, certainly much longer than the time to get into this stable state, for the system to move out of it again if measures to restore the resource are adopted. Recent progress in the speed of algorithms to find large sets of feasible limiting average rewards in ETP-ESP games, and the advent of an algorithm to establish threat points in the same class enable us to do an analysis of strong rarity value if the players are able to manipulate the system into a temporarily stable state in which the resource is made sufficiently scarce in order to profit from this optimally. The evaluation criterion underlying our analysis is the limiting average reward criterion, i.e., agents care for their long term average payoffs. Our method of analysis is closely related to the dominant mode of analysis for repeated games, i.e., we derive Folk-Theorem type of results.

Multispecies Interactions

Location: Marie-Husny

Chair: Vanessa Trijoulet

02:00 PM

Vigilance in mixed-species groups

Van Langevelde, Frank, Wageningen University, frank.vanlangevelde@wur.nl

Mixed-species groups are usually explained by foraging advantages and reduced predation risk. The optimal level of vigilance of individuals in mixed-species groups depends partly on the vigilance levels of both conspecifics and heterospecifics. However, the benefits and costs do not need to be evenly distributed between the species. We modelled the evolutionary stable strategy (ESS) for the optimal level of vigilance of an individual in a mixed-species group. We depict the vigilance game in a mixed-species group with two species using their respective ESS level of vigilance as function of the average vigilance level of the other species.

02:30 PM

A predator-prey model for bald eagles and colonial seabirds in the Pacific Northwest of North America

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Bald eagle populations in North America rebounded in the latter part of the twentieth century. An unintended consequence may be a negative impact on seabirds. We fit a Lotka-Volterra-type predator-prey model to eagle and colonial seabird data collected most years between 1980 and 2016. The model fit the data with generalized $R^2 = 0.82$, supporting the hypothesis that the seabird dynamics were due largely to eagle population dynamics. Point estimates of the model parameters indicated approach to stable coexistence. Within the 95% confidence intervals for the parameters, however, 11.0% of bootstrapped parameter vectors predicted seabird colony extinction.

03:00 PM

Performance of a state-space multispecies model: what are the consequences of ignoring predation and process errors in stock assessments?

Trijoulet, Vanessa, DTU, vttri@aqu.dtu.dk

Fay, Gavin, SMAST

Miller, Timothy J., NOAA

Little is known on how ignoring predation and process errors in fish assessment can affect the perception of the stocks. We developed a multispecies model that simulated data with observation and process errors. Four estimation models that differed by accounting or not for predation or process errors were fitted to the data and model bias was calculated. Ignoring predation had the largest impact on stock perception, and resulted in large bias in parameters and outputs. Ignoring process errors showed limited bias. If predation is large, assuming a constant mortality over time and/or age could have large consequences on tactical advice.

May 24, 2019

Methodology 2

Location: Banque CIBC

Chair: Rouillon, Sébastien, University of Bordeaux

08:30 AM

Contraction approach to optimization problems

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Consider an infinite horizon, multi-dimensional optimization problem with arbitrary but finite periodicity in discrete time. The problem can be posed as a set of coupled equations. We show that it is a special case of a more general class of contraction problems which has a unique solution obtained by an iterative process. Special cases include the classical Bellman problem and its stochastic problem formulations. Thus, we view our approach as an extension of the Bellman problem to the special case of non-autonomy that periodicity represents, and we thereby pave the way for consistent and rigorous treatment of, for example, seasonality in discrete, dynamic optimization and certain types of dynamic games. We demonstrate our results with two examples; a case with a simple periodic variation in the objective function and a simple dynamic game.

09:00 AM

Insurance and forest rotation decisions under storm risk

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Brunette, Marielle, INRA, marielle.brunette@inra.fr

In this paper, we analyze the impact of the forest owner's insurance decision on forest management under storm risk. First, we introduce insurance decision into the Faustmann optimal rotation model under risk, and we derive analytical expressions for the optimal cutting age. Second, we integrate the forest owner's risk preferences into the model. Third, the definition of the insurance terms is principally based on the level of the expected loss. As the loss is endogenous to the forest management, we propose to model the microeconomic behavior of the insurer in order to precisely define the components of the insurance contract.

09:30 AM Industry consolidation under spatial-dynamic externalities

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Abbott, Joshua, Arizona State University, joshua.k.abbott@asu.edu

This paper investigates how spatial externalities can drive firms' consolidation. Theory suggests that intra-industry spatial externalities create incentives for affected producers to take control of polluting neighboring assets through mergers and acquisitions. We develop a model with asymmetric spatial cross-contamination among plants to test empirically if consolidation in Norwegian salmon aquaculture was partly motivated by internalization of parasitic externalities. Our unique plant-level dataset includes detailed information on production, environmental quality, and financial indicators. We find evidence that firms make acquisitions to mitigate contamination risk. Consequently, the presence of an important externality may have understudied implications for an industry's structure.

10:00 AM A physico-economic model of orbital management

Rouillon, Sébastien, GREThA - University of Bordeaux, sebastien.rouillon@u-bordeaux.fr

We solve a stylized physico-economic model of orbital environment and space activity, in order to analyse the externality caused by the accumulation of space debris. In line with Gordon (1954) and Schaeffer (1957), we focus on the long term equilibrium of the orbit, induced by a constant rate of launching forever. We show that if, in the long run, the risk of satellite destruction by collision is increasing and convex with the launch rate and becomes arbitrarily large for finite values of the latter, then the curve representing the long term expected number of functioning satellites, as a function of the launch rate, has a reversed-U shape. Classically, we then define and compare typical ways of managing the orbital environment (maximum carrying capacity, open-access, social optimum). The maximum carrying capacity is defined as the maximum expected number of satellites that the orbit can sustain in the long run. The physico-economic equilibrium launch rate, that would presumably emerge under conditions of open-access to the orbit, is defined as the rate of launching such that the space sector makes no profit. Finally, the socially optimal rate of launching is the one that maximizes the present value profit of the space sector per launching campaign.

Resilience in the Digital Age

Location: Hélène-Desmarais

Chair: Rousseau, Christiane, Université de Montréal

08:30 AM Links between sustainability standards, maximin, and viability: methods and applications

Gajardo, Pedro, Departamento de Matemática, Universidad Técnica Federico Santa María, pedro.gajardo@usm.cl

The maximin criterion, as the highest performance that can be sustained over time, promotes intergenerational equity, a pivotal issue for sustainability. The viable control approach, by investigating trajectories and actions complying over time with various standards and constraints, provides major insights into strong sustainability. In this presentation we address the links between maximin and viability approaches in a multi-criteria context, showing practical methods for computing sustainability standards based in dynamic programming principle and level-set approach, together with some cases of studies concerning Chilean marine resources. This talk is based on joint works with Luc Doyen, Cristopher Hermosilla, and Sebastián Torres.

09:00 AM Fisheries management spillovers mediated by international fish markets

Quaas, Martin, Leipzig University, martin.quaas@idiv.de
Requate, Till, Kiel University

Global fish markets couple harvesting incentives across fisheries world-wide. We set up a theoretical model to study how unilateral management changes for a domestic stock affect bio-economic dynamics of a foreign fish stock that is harvested under open access conditions. We find that more restrictive fishing quotas for the domestic stock may shift the open-access equilibrium for the foreign stock from a relatively productive state to a collapsed state with low harvest rates. We further find that unilaterally optimal domestic fisheries management should take the terms-of-trade effect on the world-market price into account, as this also tends to stabilize the productive steady state in the foreign

country. If domestic fisheries management additionally takes into account existence values, a combination of a tariff (export subsidy) and a domestic quota is shown to be second best optimal. The outcomes for the foreign fishery may be stabilizing or destabilizing depending on the relative preference for domestic or foreign stock existence.

09:30 AM **Assessing fishery sustainable management and rebuilding plans under uncertainties through stochastic viability theory**

Ramírez, Hector, Universidad de Chile, hramirez@dim.uchile.cl

This talk discusses about the application of the stochastic viability theory to the management of natural resources. More specifically, we use this approach to propose and to assess exploitation strategies, as well as rebuilding plans, that permits a long-term sustainable fishery management. This methodology is applied to some Chilean fisheries.

10:00 AM **Data representation and the collective management of natural commons**

Sinclair-Desgagné, Bernard, HEC Montréal, bsd@hec.ca

Environmental services are typically subject to threshold effects: if encroachment on their supporting ecosystem exceeds a certain level, their supply will collapse. Moreover, the specific location of these thresholds is often uncertain. Current economic wisdom holds, though, that such uncertainty should have a positive impact on the preservation of natural services, because risk-aversion would lead all members of the commons to reduce their individual consumption. This conclusion, however, is not robust to whether data about an uncertain threshold yields a unimodal or a multimodal distribution (the latter being a source of greater uncertainty and polarization). Using a variant of the Nash demand game with two random thresholds, two types of Nash equilibria typically coexist: cautious (respectively, dangerous) equilibria in which agents coordinate on the lower threshold (resp. the higher threshold). When both types of equilibria coexist, the symmetric dangerous equilibrium remains Pareto dominated by the symmetric cautious equilibrium, and the latter is always Pareto efficient. We use an experimental setting to assess the severity of the coordination and equilibrium selection problem. While cautious (resp. dangerous) play is decreasing (resp. increasing) in the probability that the threshold is high, coordination failures are salient for intermediate probabilities where the likelihood of coexistence of both type of equilibria is high. We find that there is a U-shaped relationship between overall coordination and the probability that the threshold is high.

Agriculture Economics

Location: Marie-Husny

Chair: Martinet, Vincent, INRA

08:30 AM **Bio-economic modelling of competitive biomass crops' supply in Europe**

Ben Fradj, Nosra, Institute of Soil Science and Plant Cultivation, Dept. of Bioeconomy and Systems Analysis, nosrabenfradj@iung.pulawy.pl

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Gabrielle, Benoit, UMR ECOSYS, INRA, AgroParisTech, Université Paris-Saclay, benoit.gabrielle@agroparistech.fr

Matyka, Mariusz, Institute of Soil Science and Plant Cultivation, Dept. of Bioeconomy and Systems Analysis, mmatyka@iung.pulawy.pl

This study aims at analysing the agricultural, environmental and economic performance of two promising perennial candidates for the development of bio-economy, namely miscanthus and switchgrass. A bio-economic approach is used, based on integrating N yield and emission functions, simulated by an agro-ecosystem model CERES-EGC, into an agricultural supply model, AROPAj. An inter-temporal program is developed to compute the optimal biomass yield and N level that maximise the farmer profitability. Results show that miscanthus and switchgrass compete with each other for natural resources (fertile vs poor soil quality), agricultural land use (cropland vs grassland), and profitability (high vs low establishment costs).

09:00 AM Using simulation-based optimization to inform water usage policy in agricultural regions

Jenkins, Lea, Clemson University, lea@clemson.edu

Kavanagh, Kathleen, Clarkson University, kkavanag@clarkson.edu

Public policy decisions related to resource management require resolution of competing objectives. The resource management choices are also made without a clear idea of the availability of the resource. Allocation of water supplies is critically important; overuse combined with severe drought have damaged aquifers. The imbalances in aquifer levels are dire in agricultural regions, as 80% of groundwater withdrawals are used for irrigation. Our multidisciplinary research team has developed a software environment to aid the evaluation of water conservation and water supplementation strategies. We use simulation-based optimization to analyze a suite of available options and provide analytics on possible solutions. These data can be used to guide decisions with community support. The talk includes information on case studies and our path forward.

09:30 AM Time evolution of a differentiated oligopoly: the case of sustainable wine

Breton, Michèle, HEC Montréal, michele.breton@hec.ca

Sbragia, Lucia, Durham Business School, lucia.sbragia@gmail.com

We study the time evolution of a vertically and horizontally differentiated oligopolistic industry, where firms compete in quantity and are divided into groups producing one variety of a substitutable product. We assume that firms can periodically revise their decision about which variety to produce. Our results are applied to the case of the sustainable wine industry. We characterize the industry composition in the steady state as a function of the parameter values.

10:00 AM Defining, assessing, and measuring biological control: an ecological-economic modeling approach

Martinet, Vincent, INRA, vincent.martinet@grignon.inra.fr

The paper discusses the definition of the biological control ecosystem service. It compares different measurement metrics, used respectively by ecologists and economists, and relates these metrics to different definitions of the service and assessment methods. An ecological-economic model of agricultural land-use, pest and predators dynamics is developed to generate simulation data, making it possible to explore a large variety of agronomic, ecological and economic contexts, and obtain exact measures of each indicator, to compare their prediction power.

Plenary 2

Location: Banque CIBC

Chair: Doyen, Luc, CNRS

11:00 AM Threshold risk and uncertainty quantification in environmental modelling

Filar, Jerzy, University of Queensland, j.filar@uq.edu.au

Mathematical models of environmental problems often demand understanding of complex dynamics and interactions between many physical and biological variables on the one hand, and human inputs on the other. Uncertainties accompanying such models stem from multiple sources. Sometimes they manifest themselves as cascading errors and at other times they involve the risk of key variables crossing undesirable thresholds. In both cases they undermine confidence in either the model or, worse still, the underlying science. We discuss these issues with illustrations from certain generic areas such as models of fishery management and integrated climate change models.

12:00 PM Closing Session