UNIVERSITÉ CÔTE D'AZUR

Université Côte d'Azur commitments towards the Sustainable Development Goals

REPORT FOR 2022

Cross-SDGs Academic Advocacy pieces from UniCA community

This collection, dedicated to SDG13, is in no way a guide to show the way but a decision to go beyond an institutional position statement. To do this, the University engaged with its community to publish an Academic Advocacy Collection to support an official position irrigated by research in response to SDG13.

This Academic Advocacy Collection incarnates the holistic approach that must be adopted to tackle climate change and its impact. Furthermore, these Advocacies demonstrate how interlinked SDGs as they not only address the different targets set for SDG13, but also various other SDG as detailed below.

Bridging the gap between marine biodiversity conservation and food safety : a one health approach to harmful algal blooms

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Harmful algal blooms

Virtually every country in the world is now directly, or indirectly, affected by harmful blooms of microscopic algae or phytoplankton. These harmful algal blooms (HABs) can kill marine organisms and even be fatal to humans. By contaminating seafood, air and bathing waters, toxin-producing HABs threaten fisheries, aquaculture farms, tourism and human health, and cause economic losses. Non-toxic HABs also negatively affect the environment and human activities through production of high biomass and by causing seawater discolorations, anoxia and mucilage. With the growth of coastal population density and of aquaculture production and trade to meet a growing demand for seafood, the number of events associated with HABs have been increasing globally.

In temperate areas, such as in the Mediterranean sea, harmful algal bloom (HAB) events have been increasing over the last 30 years (Hallegraeff et al 2021, based on records available in the Harmful Algae Event Database, HAEDAT (http://haedat.iode.org)), and HABs in benthic systems are of particular concern. They mostly involve blooms of the toxic species *Ostreopsis* cf *ovata* that reoccur yearly, covering macroalgae growing on rocky shores and evolving as mucilaginous floating aggregates that can lead to mortalities of benthic organisms and human illness through skin contact and inhalation of aerosols (Jauzen et al. 2018). Such events are now also occurring on the French Atlantic coast, and they led in 2021 to the closure of beaches and 800 confirmed cases of intoxication during the high tourist season. In addition, emerging risks are being identified with the occurrence of species from the genus *Gambierdiscus*, which are responsible for ciguatera poisoning, and from the genus *Karenia*, responsible for neurotoxic shellfish poisoning (Arnich, 2021; Amzil, 2021; Hort et al, 2021).

Whether in temperate or in tropical coral areas, anthropogenic and climate-related deterioration of the marine environment and associated shifts in habitat-forming dominants (known as regime-shifts) are suspected to play an important role in the occurrence and toxicity of HAB species (Montserra et al, 2022, Fricke et al 2018, Gianni et al, 2018), and thus in the contamination of seafood and in the risk of human poisonings. In the Mediterranean, healthy habitats dominated by forest-forming macroalgae (i.e., *Cystoseira s.l.* species) or the seagrass *Posidonia oceanica* are being replaced with less complex communities (macroalgae by algal turfs and seagrasses by dead mat covered with ephemeral species). These changes have been attributed to multiple stressors directly linked to anthropogenic activities, including the urbanization of coasts, tourism, grazer proliferation resulting from disruption of natural food webs, overfishing, water quality, mechanical stress, and climate change (Fricket et al, 2018, Giani et al, 2018). In these shifted, deteriorated habitats, toxic benthic microalgae appear to thrive, though the mechanisms that favour their growth and potential toxicity in these alternative habitats have yet to be determined.

In this context, ECOSEAS laboratory at Université Cote d'Azur, is now assessing the effects of abrupt changes (due to climate change, but not exclusively) on benthic communities including toxic phytoplankton and vulnerable habitats. It will bridge the gap between marine biodiversity conservation and food safety through the assessment of biotoxin production and transfer in marine ecosystems using innovative transdisciplinary approaches involving ecotoxicology, chemistry, geographic information systems, and mathematical models. This research aims at developing nature-based mitigation solutions and prediction tools to facilitate coastal and fishery management and promote key habitat conservation.

This research on marine biodiversity conservation and food safety, developed following a "One health" approach, links human health, aimal health and the ecological state of ecosystems, and is in line with the UN SDGs 14, 13, 2 and 3.

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Building resilience capabilities to meet challenges induced by climate change

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I. Introduction

Climate change is identified as one of the main factors responsible for the rise of diverse natural disasters all around the world and points to a pressing need for the decarbonisation of the worldwide economy.

Natural disasters are causing severe damage affecting the lives of entire populations. In the past 30 years the number of incidents has tripled and the prediction is that this tendency will only increase. [1] Dealing with natural disasters constitutes a grand challenge for the diverse stakeholders involved in post-disaster management. First, some stakeholders (e.g., medical assistance teams, civil defence, firefighters) have to make decisions and take actions in the immediate aftermath of the disaster, that is to say, in a particularly complex context of uncertainty and urgency. The post-disaster scenario is characterised by unpredictable causal chains generated by domino effects. Second, once the crisis is over, other stakeholders (e.g., personnel of the State services, government staff) have to manage the long-term dynamics of the post-disaster recovery of the affected region. Consequently, natural disasters induced by climate change bring to the surface the issue of regional resilience. The latter involves the capacity to conserve vital processes in face of perturbations, and then to reconstruct and transform the region in a flexible manner, thus enabling learning, change, and adaptation. [2]

The pressing call for the decarbonisation of the economy is changing attitudes towards the nuclear industry. In the new context, nuclear energy appears to be a powerful contender to replace fossil fuels, or at least is becoming an unavoidable option from an energy-mix perspective, bringing to the forefront the question of «almost safe systems». The call for decarbonisation is also significantly changing other industries, such as the cement industry, called upon to replace fossil fuels. The massive use of secondary fuels instead of fossil ones becomes an urgent imperative. However, cement production sites are unprepared for such a rapid change, which makes the monitoring of their industrial processes more complex and riskier than usual. As a result, in many industries, including the nuclear and cement industries, managing safety becomes even more important. Safety management involves two forms of organisational safety: regulated and managed. While regulated safety relies on technical and procedural barriers to cope with predictable events and is aimed at reducing uncertainty, managed safety aims to develop organisational capabilities to proactively deal with unpredictable events, and thus to deal with uncertainty. In other words, managed safety requires the development of resilience.

II. Defining resilience

In recent years the popularity of the concept of resilience has grown exponentially in the management literature aiming to address organisational capabilities to reach positive outcomes despite adversity. [3] In the case of natural disasters, adversity comes from disruptive events, which are unique, unprecedented, or even uncategorisable. In the case of nuclear power plants or other high-risk organisations, adversity refers to a context characterised by a constant exposure to potential accidents. In general, withstanding adversity relates to dealing with complex, ambiguous and uncertain situations. Because resilience is context-sensitive and multidimensional, it is defined as the capability to cope with unanticipated threats and to deal with unexpected events characteristic of complex situations. This capability depends on people's ability to make sense of what is happening around them and to develop appropriate customised responses for navigating the altered environment, [4] instead of applying pre-determined ones. Such capability refers to the concept of mindfulness characterised by focus on "the here and now" and both stable (focused) and vivid (producing rich interpretations) attention, which contribute to designing responses, which are tailored to real-time events. The development of the resilience capability involves three different stages: 1) the preparedness stage, consisting in training people to deal with uncertainty, i.e., to be mindful; 2) the proactive stage, involving the development of people's ability to be mindful and to learn from experience in order to deal with incubating threats; and 3) the reactive stage, involving the development of people's ability (a) in the short term – to manage the unpredictable causal chains immediately after the adverse event, and (b) in the long term – to learn from adverse events and to recover from disasters as well as to prepare for the future.

Notwithstanding increasing scholarly interest in the topic, many questions remain regarding the development of resilience capabilities in practice. More specifically, it remains unclear how resilience capabilities are built and how they relate to specific processes such as sensemaking, decision-making and learning. [5] As developed in parts II and III below, our Université Côte d'Azur (UCA) team is conducting research aiming at providing answers to these questions.

III. Building territorial resilience capabilities to deal with disruptive events

The UCA team is involved in two ongoing research projects on the development of regional resilience capabilities in the context of natural disasters.

The first project, **IMPACT-A: Immediate Management Planning ACTion – Assessment**, addresses resilience in terms of preparedness (stage 1) to cope with the unexpected in the case of disruptive events (natural disasters). Stakeholders who have to manage the event that just happened and its domino effects (unpredictable chain of causalities) have to be prepared to do it; they have to learn to be mindful, both individually and collectively. In other words, IMPACT-A addresses the link between training and mindfulness in complex situations. Its aim is both scientific and managerial. From the scientific point of view, the objective is to provide a better understanding of the complex relationships between learning and mindfulness, which need further theoretical and empirical investigation. [6] From the managerial point of view, the objective consists in the evaluation and

the improvement of the IMPACT module, in close collaboration with its designer, LCL F. Castagnola (Risks management training – Crisis management – Service Départemental d'Incendie et de Secours des Alpes Maritimes). The IMPACT module is an innovative training module, which enables individuals and groups to become resilient (mindful). It consists of an advanced training aiming at the development of cognitive flexibility and improvisation, i.e., a training that allows the participants to learn how to detach themselves from the existing interpretive schemes and procedures, to adapt to all types of events, including those related to natural disasters. In other words, the IMPACT module, which is offered in many countries all around the world, is a training in proactive resilience. The aim of the second, PhD, project[7] is to better understand the process of building regional resilience capabilities in the post-natural disaster context. In this research, resilience is considered as the region's ability to recover from external shocks (i.e., resilience stage 3b). Due to the complexity of regional systems, building regional resilience capabilities requires inputs from many heterogeneous participants, with their diverse and complementary knowledge. These heterogeneous participants must interact and make a shared sense of the situation to collectively find innovative and lasting solutions. Even if there is a consensus that social aspects play an important role in building regional resilience capabilities, they are under-theorised in the literature. This doctoral project focuses on building regional resilience capabilities from an organisational, relational, and communicational perspective. The project is based on a comparative qualitative study of two regions devastated in October 2020 by Storm Alex (Alpes Maritimes, France). It contributes to the UCA Academy 3 FORESEE project.

IV. Building organisational resilience capabilities in hidh-risk contexts

The UCA team is engaged in three research projects on organisational resilience capabilities in high-risk contexts:

1) The **European Leadership for Safety** (ELSE) [8] project (see COP27 Contribution of Den Auwer et al.: Assessing the perception of nuclear risk) explores the process of the joint development of regulated and managed safety (resilience) and its underlying mechanisms. It is funded by the European Union through its Instrument for Nuclear Safety Cooperation (INSC) in cooperation with the International Atomic Energy Agency (IAEA). Its aim is to develop an innovative science-based approach to advanced education in the domain of leadership for safety, combining the most up-to-date academic knowledge and professional expertise.

2) The **Decommissioning: Management and Leadership for Safety Education** (DMaLSE) project focuses on organisational resilience capabilities at the scale of a megaproject. As many installations reach the end of their service life, governments, nuclear regulators, and operators are increasingly concerned with dismantling of nuclear power plants (NPPs). According to a recent report of the international consultancy agency, Deloitte, 56 nuclear facilities worldwide are currently in the phase of decommissioning and more than 400, including NPPs and research reactors, are expected to phase out by 2040. Decommissioning projects are confronted with a particularly high level of uncertainty due to their high complexity. They are highly complex not only from a technical but also from an organisational and managerial perspective (i.e., in their design, planning and execution) as they involve the coordination of numerous interdisciplinary stakeholders over a very long period – typically 20 to 30 years – creating many safety challenges. Among the safety challenges, one concerns the development of organisational capabilities to manage complexity and uncertainty in megaprojects over a long period. DMaLSE is in the final stage of negotiations to be funded by the European Union. Its main innovation consists in the development of a science-based approach to education on leadership and management for safety related to nuclear decommissioning. The Lead Applicant is Université Côte d'Azur and Co-Applicants are SKEMA Business School[9] and Karlsruher Institut für Technologie.

3) The **Resilience Capabilities in Dynamic Work Settings** (ReCaWS) project focuses on resilience capabilities at the scale of operational teams. It is conducted in a cement plant faced with the imperative of decarbonising its activity. The study context is the cement plant manufacturing department where operational teams operate in an unpredictable, dynamic, and complex task environment. The manufacturing process, especially its combustion stage, is not programmable or predictable. It is a complex physical phenomenon. As in all cement production sites, the complexity has increased significantly as a result of rapid and continuous changes, mainly consisting in the new and massive use of alternative fuels, which create new emergent and unpredictable chemical reactions. In this context developing resilience capabilities becomes essential. Building individual (operators') and collective (teams') mindfulness, and developing mindfulness capabilities through learning appear the most challenging. The first results of this research project provide theoretical contributions on the barriers to learning and thus on the complex links between learning and mindfulness. They also provide practical contributions on how to create the conditions that foster operators' and teams' resilience capabilities in dynamic work settings. These results have been published in a ranked journal[10]. The next step in this research project will involve a comparison between organisations operating in two different risky industries, a nuclear power plant (high-risk context) and a cement production plant (less risky context) with a specific focus on learning and mindfulness.

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Digital science to contribute to the ecological transition

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I. The materiality of the immaterial

For nearly five years, more and more studies have made us aware of the materiality of digital technologies and their negative impact on the environment. The carbon footprint of digital technologies is far from negligible and, above all, it is growing exponentially: the larger it is, the faster it grows. The digital sector's share of global GHG emissions is estimated at 2 to 4%, according to studies [Freitag]. There are more terminals on the planet than inhabitants, and a data centre opens every week in the world [CCC]. Most of the GHG emissions are produced during the manufacturing process which also consumes a lot of rare metals, with serious consequences on the depletion of resources and pollution. To complete the picture, it is important to underline the strong inequalities between countries regarding digital technology: while rich countries take full advantages of ICT services, poor countries suffer from the pollution generated by the extraction of mineral resources and by the end of life of equipment. While 86% of the population in France are Internet users, only 35% in Ghana, the final resting place for e-waste from all over the world, and 6% in DRC, the world's leading producer of cobalt. The current development of digital technology is not sustainable in many respects!

Environmental footprint estimates are laden with uncertainty and should be considered as orders of magnitude. Awareness of these orders of magnitude can be sufficient to guide political choices or to take relevant legislative resolutions. It should be noted that this is a young science (just over 10 years old) and that it has made immense progress. Today, a standardized methodology (ISO 14040/44) is available: the Life Cycle Assessment (LCA) [Ligozat, Rasoldier]. It includes the environmental impacts (up to 18 indicators) of a product or service throughout its life cycle, from design to end of life, including production, transport and use.

II. The rebound effect: a stone in the backyard of green growth

This phenomenon was first observed in 1865 by the economist W.S. Jevons: coal consumption in England should have decreased due to the improved performance of steam engines, but instead it increased sharply! The efficiency of digital technologies has steadily improved since they emerged in the middle of the last century, but their carbon footprint has steadily increased. For

example, the improved energy efficiency of servers is paradoxically followed by greater energy consumption, because of the growing number of servers and calculations.
According to operators' claims, 5G technologies are expected to divide energy consumption per gigabit transported by a factor of 10 compared to 4G, once they reach maturity by 2025, and then by a factor of 20 by 2030. However, the number of Gbits transported will not remain constant. According to a study [OpenSignal] conducted in six countries, 5G users consume 2.7 times more data than 4G users. Despite a high degree of uncertainty due to many unknowns (actual deployment by operators, adoption by businesses and consumers), the carbon impact of 5G deployment in France could significantly increase the carbon footprint of digital technologies [HCC].
If the rebound effect is economically attractive, it is dramatic from an environmental point of view: part or even all of the environmental benefits obtained through improved technologies are offset by an increase in use [Combaz]. It is a stone in the backyard of green growth. Rebound effects not only concern energy efficiency. Every time a new technology is expected to save time or money, these savings are used to consume more of the same product (direct rebound effect) or another product (indirect rebound effect). Thus, any technological evolution causes induced effects that are difficult to predict and too often ignored. It is however essential to assess these effects if we want to "contribute to the evolution of digital technology by reducing its environmental impacts" [CCC].

III. Assessing the environmental benefits of a digital solution

Conversely, digital technology is considered as a 'formidable lever for the ecological transition and the fight against climate change' [CCC]. The scientific community has shown great dynamism on this subject in fields as varied as transport, construction, manufacturing, agriculture and energy. But it is essential to better evaluate the net environmental benefit of a solution, without forgetting the environmental impact of the solution itself [The Shift Project]. Some solutions may then show little or no environmental benefits if the energy gains in the use phase are offset by the environmental costs due to the manufacturing stage or end of life.
An LCA assessment is essential to decide whether or not to deploy a technology, possibly to regulate its use, and if so, not to delay alternative actions or research. However, such an evaluation is rarely carried out in scientific studies. For example, in the field of AI, the environmental impact assessment is often limited to energy consumption, neglecting the production and end-of-life of the equipment. According to [Ligozat], among 57 articles proposing applications of AI to fields with a strong potential for climate change adaptation or mitigation, half of them do not include any environmental assessment and none of them take into account the impact of machine learning!
Wherever possible, estimates should also take into account induced effects. Such estimates are difficult to conduct and involve uncertainties, but they are possible and instructive as shown by some recent works (see [Ligozat, Rasoldier]) and studies [IEA]. Research must go on! All stakeholders (universities, companies and governments) have a role to play and must collaborate to successfully complete this task.

IV. Low-tech scientific research

As awareness is growing, the idea of sufficiency is making its way. But at present, it is mostly limited to individual actions: keeping your smartphone as long as possible, limiting your video streaming time, etc. Citizens are faced with contradictory instructions: buy more to keep the economy going, consume less to avoid polluting the planet!
Rebound effects have structural causes: the growth policies of governments and companies, business strategies and social, technical and regulatory standards. These causes must be addressed first. On a global scale, the hoped-for decoupling of economic growth from all critical environmental pressures (green growth) did not happen and is unlikely to happen in the future [EEB, EEA, Parrique]. Technology alone will not allow us to continue the 'business as usual' scenario while preserving the planet's vital resources. But it could help us to implement a just and happy sufficiency: living better with less.
The aim of low-tech approaches is to address the needs of society while limiting reliance on technology [Bihouix]. The term 'low-tech' is used for the techniques, technologies, services and know-hows that follow three main principles: usefulness, accessibility and sustainability. 'They provide the keys to answer our needs, while respecting people and the planet' [Low-techs Lab]. They are eco-designed, resilient, sturdy, repairable, recyclable, agile, and functional. All over the world, initiatives are arising and developing, particularly in the South, where sufficiency is an economic reality. Some 823 projects in 87 countries in 12 areas are referenced in the Low-tech Lab database. Academic research is still hesitating to show interest in low technologies and is mostly limited to eco-design. It could become more involved, in partnership with emerging countries or with the very active "third-places", which contribute to the emergence of a new way of life based on collective intelligence and cooperation. Innovation and sufficiency are compatible!

V. Let's take a step back and develop a new imagination

Sufficiency is not an end in itself, but could be the only way to live within the planetary limits and achieve a radically different model of society based on the principles of sustainability. In order to take an active part in the unavoidable transformation of society, scientific research must also be transformed. Researchers need to take a step back and consider the effects of the technologies to which they contribute: the rebound effects but also the social effects. This requires a broader debate on scientific and technical issues, on the governance of scientific activity and on the relationship between scientific research and society [MakeSEnS].
Siloed research cannot cope with environmental issues, which are global and systemic. A common and collective approach must be developed in order to produce the necessary knowledge and build transdisciplinary communities in the long term. These communities should include not only scientists but also economists, historians, sociologists, philosophers, etc. Such spaces of discussion have emerged recently at a national level in France with the Labos1point5 collective and the GDS EcoInfo, for example, and locally within some universities [La fabrique des questions simples, Plan B]. It is essential to promote these spaces for debate, but they must also interact with society as a whole, in order to develop a new collective imagination, which is essential for society's transformation.

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[Parrique] Ralentir ou périr - Thimothée Parrique

Encouraging the use of evolutionary biology concepts and ecosystem protection to mitigate climate change causes and consequences in agriculture.

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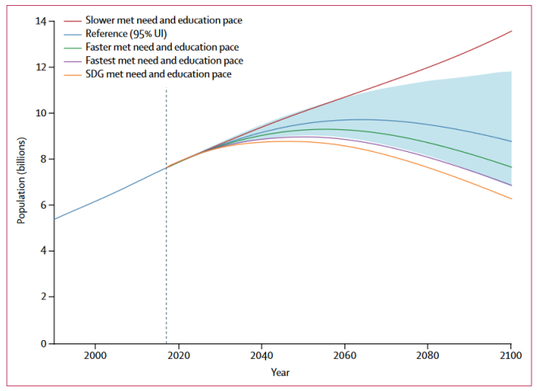
Introduction

I wrote this advocacy both as a citizen of a world changing due to climate change and biodiversity loss, and as a scientist whose research has the potential to inform translational scientists and policy makers and lead to innovations that may eventual contribute to the mitigation of climate change and its consequences.

Two main parameters directly influence climate change caused by human beings: (i) the individual impact of each citizen due to their behaviour and consumption habits, multiplied by (ii) the number of individuals on earth.



Concerning the evolution of the global human population, a recent study combining multiple scenarios forecasted a likely peak at 9.73 billion people (8.8-10.9 uncertainty interval) around 2064 (Figure 1) followed by a decrease to 8.8 billion in 2100 (6.83-11.8 uncertainty interval)[1]. This means the youth of the current generation and the next will experience the highest population levels on Earth. A peak of population translates into a peak of demand for energy, food, feed, housing, equipment, etc. putting our planet under high pressure. Although further investment in female education and access to contraception can hasten declines in fertility and slow population growth, the trend remains a growth with a peak in the next 40-45 years.

Figure 1. *Global population forecast in the reference, slower, faster, fastest, and sustainable development goal (SDG) pace scenarios, 1990–2100 according to ref[1]; UI= uncertainty interval.*

I. Advocacy as a citizen of a changing world

With this parameter of population and the associated growth in demands in mind, and regardless of the expected accompanying scientific discoveries and technological progress, collective efforts must be made to decrease individuals' environmental impact through changes in habits and behaviours. The successive reports of the Intergovernmental Panel on Climate Change (IPCC) provide clear guidelines to achieve the behavioural changes necessary to reduce human-induced greenhouse gas, a cause of climate change. However, for the population to adhere to these measures, governments and institutions must adopt irreproachable and exemplary behaviours themselves. Recently, several severe ecological nonsenses like the organisation of the FIFA World Cup in Qatar with air-conditioned open-air stadiums or the organisation of the Asian winter Olympics in the middle of the Saudi Arabian desert yield a doubly detrimental effect. First, directly as a major source of ecosystem degradation and greenhouse gas emissions, and second, these terrible examples have disastrous effects on the acceptance by populations of measures to reduce their own individual environmental impacts. These inconsistencies jeopardise a large part of the efforts spent to try to change people's behaviour and the lack of condemnation by the international community is as incomprehensible as the decision to award these events in these conditions. Although the previous generation was not sufficiently informed about the ecological consequences of their decisions and acts, there is no excuse for the current generation that knows and is widely informed but decides to ignore the consequences. This is especially true for this segment of the population which govern states, institutions or big companies and generally has a high education level. In my opinion, these nonsenses are still possible because of a feeling of total impunity. This should absolutely change, and international rules and regulations should rapidly incorporate the notion of "ecocide" at different levels up to the level of "crime against the planet", for the most terrible cases, inspired by the notion of crime against humanity. This idea of a law of ecocide has already been proposed multiple times with clear arguments and common sense, but never yet adopted [2,3]. Definitely, ecocides not only have a direct negative impact on ecosystems but a longer-term negative impact on the well-being and health of whole communities and populations, even threatening their survival. These 'crimes against the planet' should be more unanimously condemned and the informed persons responsible for these decisions should risk prosecution, prison, and fines high enough to be dissuasive. The money generated by these fines could in turn be used to support actions against climate change, including improvement of scientific education worldwide

II. Advocacy as a research scientist working on plant health

According to the 6th and latest IPCC assessment report (Chapter 2 of Working Group III), agricultural, forestry and other land use are collectively responsible for approximately 22% of human-caused greenhouse gas emissions worldwide (Figure 2). This assessment has been rated as 'robust evidence – high agreement' and places agriculture and other human-modified land usage as the third source of greenhouse gas emission globally after energy systems and industry, albeit with wide regional differences. In the agricultural sector, land use and land conversion alone are the main contributors to greenhouse gas emissions (51%). Logically, according to the IPCC report (Chapter 7 of Working Group III) the primary means of mitigation, with the single largest potential to reduce emissions, is the protection of ecosystems (forests, wetlands, savannas, and grasslands).

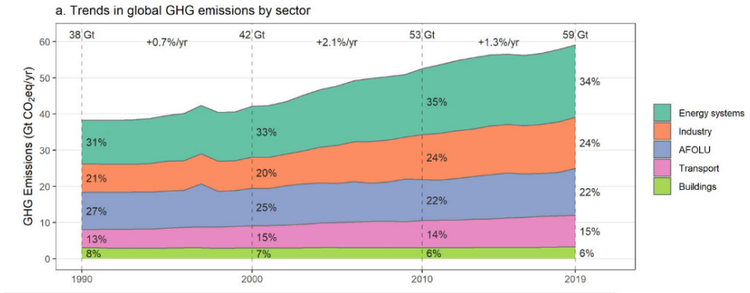


Figure 2. Total annual anthropogenic greenhouse gas emissions by major economic sector. (GHG= greenhouse gas, AFOLU= agricultural, forestry and other land use).

As noted in the introduction, the global population is growing. In addition, the diet is changing in developing countries. These two parameters will increase the global food demand and put even higher pressure on the agricultural sector. To meet the corresponding crop demand, an increase of 25-70% above current production levels will be necessary[4]. This cannot be at the cost of expanding cultured land surface as land usage and conversion is the main source of greenhouse gas emission in agriculture. Hence, the yield per surface must be improved. However, this also cannot be achieved by applying more synthetic fertilisers and pesticides, because the first is a known source of N2O greenhouse gas and the latter negatively impacts biodiversity and pollutes water and soils. In addition to progress in crop variety selection and wider usage of agroecology, more durable alternatives to currently used fertilisers and pesticides must be found. A study of five major crops that sustain the lives of billions of people (wheat, rice, maize, potato, and soybean) has shown that pests and parasites are responsible for average annual yield losses of 17.2-30.0%, depending on the crop[5]. And this is despite the considerable efforts already deployed to control them. Furthermore, climate change has been associated with reduced efficacy of pesticides[6] and the expansion of pest and parasite distributions poleward[7]. Hence, agriculture is both a cause and a victim of climate change. As an evolutionary biologist working for France's National Research Institute for Agriculture, Food and Environment (INRAE), I hope my research can contribute, even modestly, to the mitigation of climate change and biodiversity loss. My main goal is to understand how pests and parasites have evolved the ability to manipulate their hosts and how these species adapt to environmental changes including host defence systems and methods deployed to control them. I am convinced that better understanding how these species evolve and adapt will foster development of more environmentally sound, durable, and efficient solutions to reduce the damage caused by pests and parasites to agriculture. To investigate these questions, I use comparative and evolutionary genomics and bioinformatics, including artificial intelligence in collaboration with Université Côte d'Azur. Despite its high potential, evolution and its concepts have not yet fully benefited all fields of biological research and their applications[8]. I advocate a broader adoption of evolutionary biology concepts in research, including applications in the development of new control methods against agricultural pests as well as evolutionarily informed policy decisions for biodiversity protection and ecosystem preservation.

Concluding remarks

As seen in section II, protection of ecosystems is the primary means of mitigating greenhouse gas emissions in the agricultural sector, a sector under high pressure due to global population growth. This protection of ecosystems needs collective efforts and can only be realised if appropriate rules and regulations are applied. This can be achieved by enforcing ecosystem protection means, including laws allowing trials for ecocide or crimes against the planet as proposed in section I. As pest and parasites generally evolve faster and are more rapidly adapted to climate change than the hosts we want to protect, I also advocate a wider adoption of evolutionary biology concepts to help and guide development of more efficient means of mitigation.

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Living technologies, a renewed perspective of Deeptech to foster climate and ecological transitions

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Introduction

Humanity has entered the Anthropocene, a geological era in which the effects of human actions on the Earth have been demonstrated (Crutzen & Stoermer, 2000), particularly on climate and natural settings. This overall context implies engaging in efforts to adapt our societies in order to respect planetary limits (Stephen et al, 2015) and hence attenuate climate change.

The institutionalisation of climate issues is taking place at all governance levels (Chateauraynaud and Debaz, 2017). The latest report of the IPCC (Intergovernmental Panel on Climate Change) points out the weaknesses of actions implemented so far (IPCC, 2021) but shows that solutions to attenuate climate change already exist.

The French Agency of Development (AFD) recognises that climate disruption represents an industrial challenge (2017) and identifies Deeptech innovation as a means to overcome it. Deeptech is defined as the production of innovations based on intensive R&D activities conducted over a long time. Therefore research and start-up companies engaged in it are capital and time intensive.

Farming is targeted as one of the areas where efforts must be undertaken (Pachauri and Meyer 2014) to meet climate constraints. Based on a theoretical framework for characterising technologies according to their capacity to respect planetary limits, this paper aims to show that Deeptech projects for Agriculture are a good illustration that Deeptech offers the potential of developing within planetary limits at certain conditions.

1. Technologies and the Anthropocene: how can we remain within planetary limits?

As stated above, Deeptech projects and innovations have a true potential to provide solutions to address environmental and climate problems (Nedayvoda et al, 2020) however controversies have emerged relating to the sourcing of resources needed to develop, implement and market those innovations. Nedayvoda et al (2020) show that Deeptech is a way to solve complex environmental and climate challenges. It can foster productivity gains in a variety of resource-intensive industries lowering the damage to natural settings. The authors provide examples in high-tech sectors as well as in other sectors apparently less technological and yet vital such as agriculture.

They refer to our daily technological uses (digital, energies, etc.) (Meadows et al., 1972, 1992, 2012; Murphy et al., 2021) but the same is true for basic consumption such as our daily food intake (Bowles et al., 2019). In this paper, we propose to delve into a theoretical framework that proposes a classification of technologies according to their long-term capacity to foster a sustainable future.

This emerging theoretical framework classifies technology properties according to their capacity to ensure the cohabitation on earth of human and other living entities. According to José Halloy et al. (2020, p 120), technologies must be analysed within the framework of the «Anthropocene». The question then is whether a technical system is sustainable from an ecological perspective over a long period, in opposition to technical systems that have detrimental effects due to their impact on non-renewable resources and/or on natural settings.

Within this perspective, sustainability is reframed as all the materials, processes (production, development, maintenance, etc.) and activities that can last in the long term without depleting non-renewable resources in particular those of carbon-based fossil origin (coal, oil and gas) or even using them (Halloy et al, 2020).

The framework proposed by Halloy et al (2020) was formalized by Monnin (2021a) as follows and differentiates Zombie from Living technologies.

	Resources	Sustainability	End of Life
Zombie technologies	Finite (long-term exhaustion)	Minimum durability in working order	Maximum life span as waste
Living Technologies	Renewable (strong sustainability)	Maximum durability in working order	Minimum life span as waste

Table 1: translated from Monnin (2021a, p.21)

In this context, the author (Monnin, 2021) points out that zombie technologies are non-recyclable and in the rare cases where they are, it implies that they use an amount of fossil energy that makes it inefficient from a deep ecological perspective.

While most Deeptech solutions are high-tech technologies that will revolutionise the world (Nedayvoda, 2020), they are mostly digital technologies that use non-renewable materials (drones, satellites, AI, etc.), and according to the theoretical framework, they are considered "Zombie technologies" because they require a variety of resources such as minerals for their manufacture, energy for their use through digital networks and are barely recyclable due to lack of knowledge in this area.

This view of innovation is however restrictive and other perspectives exist. The new "European Innovation Agenda" by the European Commission (2022a) has called for solutions targeting key societal challenges. As in the case of wind energy, bold policy choices, such as those dealing with climate change and environmental protection, require close cooperation between the public and private sectors. Policies are prompted to change due to both the covid crisis and the war in Ukraine.

In this context, the European Union includes ideas such as a circular economy and a resource-efficient economy in addition to digital technologies and recognises the need for companies to build new capabilities both in terms of their production, trade and collaboration (European Commission

2022a). We believe that thinking in terms of zombie and living technologies has the potential to fuel such an ambition.

Deeptech is the outcome of public or private research. Nowadays, research on sustainable technologies over the long term remains very marginal. Creativity is needed to allow sustainable technologies to emerge and to build living technologies that respect the biophysical constraints of the Earth system and preserve the sustainability of humanity.

The next section provides an example of the use of living technology in a sector that is highly important, agriculture.

2. Using living technology for food: emergent technologies in agriculture

The weight of agriculture in the climate and environmental crisis is well identified and measured (IPCC 2021), in particular the use of pesticides that corresponds to a planetary 'negative common' (Monnin 2021b) in the sense that it has an impact on the long term and must be dealt with by communities. Public policy can act in different time frames both to eradicate pesticides and transform farming activities for the future. The European Union in its "Farm to Fork" strategy (European Commission 2019) aims to develop sustainable food production, however, it still specifies "that digital technology is key to success" (European Commission 2022b p. 6) through the optimization of pesticide use with the IoT. If those solutions need to be explored, they originate from non-renewable resources and have minimum durability in working order and a maximum life span as waste, as such they can be classified as a zombie technology (Monnin 2021a; Haloy et al 2021).

In the next section, we present living technologies developed within Université Côte d'Azur that have the potential to contribute to the agroecological transformation.

To achieve farming at a level that offers sufficient food resources, pesticides can be optimised through farming 4.0 solutions, but other biological biobased solutions are available that can lead to pesticide suppression. Université Côte d'Azur with INRAE has a long-standing history in biological control[1] (hereafter biocontrol) research and development for farming with its research centre Institut Sophia Agrobiotech (ISA). Biocontrol implies the use of different kinds of biological entities to help farmers in their growing activities. This can be microorganisms such as bacteria or microorganisms such as insects but also natural chemical compounds such as pheromones.

Biocontrol involves four different strategies to fight against pests that range from the more usual practices which farmers are used to, to strategies that imply a natural equilibrium in the long run. The four strategies are conservation biocontrol, classical biocontrol, inoculation biocontrol and inundation (also augmentative) biocontrol.

Inundation biocontrol implies repeated use each year, and it corresponds to current practices. All the other strategies are far removed from current farming practices. The development of biocontrol techniques is a viable solution to achieve the agroecological transition and presents opportunities to develop Deeptech innovations. Boutet and Parmentier-Cajaiba (2022) showed that the very properties of each class of biocontrol call for adapted business models (Boutet & Parmentier-Cajaiba, 2022). It means that to develop the full potential of the different forms of biocontrol, society needs to think outside the box of current farming practices and innovate to develop and disseminate these innovations that can, in the long run, be consistent with deep ecology requirements.

[1] 'The use of living organisms to suppress the population density or impact of a specific pest organism, making it less abundant or less damaging than it would otherwise be' (Eilenberg, Hajek and Lomer, 2001)

Conclusion

Université Côte d'Azur is already a stakeholder in this transformation. Thanks to the Initiative of Excellence Label, several programs have been created, such as Academy 4 "Complexity and diversity of living systems", which support innovative, original, and quality projects in life sciences that have an impact on national and international research. Université Côte d'Azur also supports Deeptech in biocontrol projects such as Mycophyto and entrepreneurship projects such as Evolutiv Agronomy and Agroinnov.

This example in farming shows that Deeptech has the potential to contribute to ecological transformation but must meet a threefold challenge: find ways to integrate living technologies both in production processes and uses, think about different time frames to achieve a transition within the planetary limits that remain socially acceptable, and accept that it is not only a question of product substitution but of changing our way of living.

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Materials science contributing to the sustainable future

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In the view of the problems related to global climate changes, I would like to advocate for the responsible use of biomass for making sustainable materials. To do this, I will be using the principles of Green Chemistry, and I will apply them to materials science.
Green Chemistry principles contain twelve general statements /1/ that should guide not only chemists, but also materials scientists, towards responsible and sustainable research and innovation. To say it simply: we, who are inventing new materials and processes, from molecules to the final product, must be reflective in our practice, and consider the environmental impact and consequences of our work and our processes. Below I will give some examples of Green Chemistry approaches, and I will also focus on the use of renewable feedstocks, which is the area of my research and is one of the principles of Green Chemistry.
I would like to start with the main principles that should be considered whatever is the origin of starting matter, the way of making a molecule or material and its application. First, it is better to prevent/decrease waste than to treat or clean it up after it has been created. To estimate and quantify the "fraction of waste" (it is called "E-factor" /2/) produced during synthesis of a new matter or making a new product, a simple formula was suggested:

$$E\ factor = \frac{total\ weight\ of\ waste\ produced\ to\ make\ a\ product}{weight\ of\ the\ product}$$

Another way to think about avoiding waste as much as possible is to consider "atom economy" /3/:

$$Atom\ Economy = \frac{weight\ of\ atoms\ of\ the\ product}{weight\ of\ atoms\ of\ reactants}$$

As matter is always related to energy, the processes should be energy efficient. This means that we should make every effort to enable the decrease of energy use. A basic example is to perform synthesis or make materials at ambient temperature and pressure, when possible.

Let us now focus on the use of the renewable feedstocks. The world around us relies on photosynthesis performed by Nature, which uses CO2, light and water and produces oxygen and sugars, the latter being the source of energy, chemicals and materials. Photosynthesis is a complex process that we, humans, cannot reproduce yet; fortunately, Nature is doing this continuously. For the time being, we use only about 3-4% of the biomass produced on the Earth. It does not mean that we should exhaust the Nature's Bounty, but we can make more use of natural resources and do so in a sustainable way. For example, we can use biomass to produce energy, chemicals and materials. Below I would like to give three examples related to the use of biomass: biorefinery approach, "old" matter for new materials and applications, and alternative biomass resources.

One of the best examples of sustainable approaches in using biomass is biorefinery. In its ideal form, this means "no waste" when converting biomass into energy and materials. For example, processing of lignocellulose biomass under the concept of biorefinery is gaining more and more attention /4/ and starts to be applied by pulp and paper companies. They become the producers not only of cellulose fibers for paper and textile, but also of fine chemicals, biofuels and new materials such as nanocellulose - for coating, cosmetics, pharmacology, biomedical, and materials-for-energy applications. Still, there are numerous challenges to overcome as lignocellulose is a complex and multicomponent composite material requiring specific processing routes due its recalcitrance; this requires new research paradigms and approaches, and new chemistry. The adequate application of biorefinery approach also needs the development of new infrastructure and logistics.

Interdisciplinary research can lead to the creation of new materials from well-known biomass for unanticipated and exciting applications. Here I would like to mention so-called bio-aerogels that are lightweight nanostructured fully bio-based materials /5/. For example, we used pectin, which is a gelling agent in food, for making aerogels that turned out to possess very low thermal conductivity and thus are extremely attractive for use in thermal insulation /6/. The same bio-aerogels can also be used as delivery matrices for controlled release of active substances for pharmaceutical and bio-medical applications /7/. Keeping in mind the principles of Green Chemistry, we are now working not only on the improvement of bio-aerogels' performance, but also on consuming less energy in the processing stages.

When using biomass, one of the important issues is to avoid competition with food when producing materials or energy. Alternative sources should thus be considered, such as, for example, microalgae /8/. The combination of biotechnology, chemistry and materials science can lead to a rich and stimulating interdisciplinary collaboration resulting in materials and processes that make our lives not only greener, but better.

It should be noted that not all materials from biomass and processes of making them are sustainable. Biomass-based materials must not be "toxic" (in the large sense of the term) to the biosphere. Biodegradability must be considered. To evaluate material sustainability, life cycle assessment from "cradle to cradle" need to be performed: it makes an inventory of resources, energy used to make a product and generated waste, i.e. from gathering the raw matter to the end of product life and even to its "rebirth".

To conclude, we are still at the beginning of a long way towards a sustainable future, and one of the solutions is a responsible use of the biomass. A lot of efforts and investments are still needed to stimulate the research and bridge the gap between the academia and industry. Our young generation needs a sustainable future and materials science should and can contribute to its development. I call on research colleagues, educators, and policy makers to redouble their efforts in promoting this broad agenda, as well as popularising and adhering to Green Chemistry principles more specifically.

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Radioecology, assessing the impact of nuclear activities on marine ecosystems

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I. Positioning [1]

In the context of climate change and the goals established in the 2015 Paris Agreement, nuclear power has been identified as a viable alternative (although not unique) to the use of fossil fuel-based energies.[2] This, of course, has and will raise social, political and scientific concerns over an eventual accident or misuse of nuclear power, legacy, long-term management of waste and the possible impact on the environment. Although exposure to radionuclides and radiation does not constitute a day-to-day issue of public health, concerns become more acute in the case of a nuclear event or a deficiency in waste management and the possibility of exposure raises constant questioning from society and underlines the need for information and scientific input.

The three major civilian accidents of Three Mile Island, Chernobyl and Fukushima in March 1979, April 1986 and March 2011, respectively, contributed significantly to the need to assess the impact of radionuclide release in the environment. At the same time, remediation technologies have always been a challenging operation, since they are highly dependent on the physical and chemical history of the site under consideration. Finally, the legacy of historical nuclear storage and test sites such as Mayak in Russia, Sellafield in UK or Hanford in the USA (not exhaustive) also contributes to radionuclide dissemination. These factors, in addition to the general, social and political concerns on environmental impact, continue to drive fundamental scientific questions regarding any further accidental release of radionuclides on the Earth's surface.

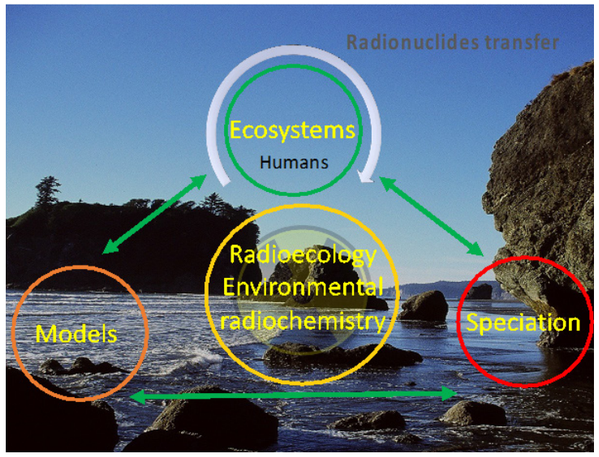
Most studies in radioecology and environmental radiochemistry have intended to inventory as well as assess the fate and impact of minus levels of radionuclides in specific compartments (e.g., minerals, sediments, water, plants, organisms). This approach enables monitoring of the transfer and accumulation momenta at very large scales, however, it often fails to describe the chemical form of the element in question due to the very low levels of radioactive elements. Therefore the chemical reactions at the molecular level remain hardly decipherable because it is technically impossible (due to large dilution factors) to assess direct speciation. From the IUPAC gold book, speciation is defined as the «distribution of an element amongst defined chemical species in a system». [3] In consequence, not only the quantity (the dose) but also the chemical form (speciation) are essential input data. [4] Despite those limitations, attempts to better understand the migration and accumulation transfers to the environment and ecosystems have raised further questions.

Since the beginning of environmental radiochemistry research in Nice in 1980, the approach has shifted over time from pure radioecology to a radioecology combined with environmental radiochemistry and even biochemistry. The major difficulty in achieving this goal is to combine two orthogonal scales: the ultra-trace concentration scale on the one hand (in atoms per volume or surface units) and the large spatial heterogeneities of the field on the other hand (in length units).

II. Environmental (marine) studies with radionuclides

On one hand, the environmental chemistry of radionuclides refers to the chemical study of Metallic Trace Radionuclides in environmental systems. On the other, radioecology is a subdivision of ecology that «emerged as a scientific discipline at the end of World War II, in response to environmental problems from radioactive fallout associated with nuclear weapons testing».[5] This historical view of radioecology seems to exclude, although by omission, possible effects of natural radioactivity (radiations) on ecosystems. During the first decades after World War II, radioecology studies were driven by the study of the impact of nuclear radiation and transfer of radionuclides to ecosystems.

As stated in a recent viewpoint on radioecology from Rhodes and coworkers, "There is a growing desire to incorporate attributes of ecosystem science into radiological risk assessment and radioecological research […]»5 putting radioecology (mostly at very low doses) into the larger perspective of ecological risk assessment (see also publications from the International Commission on Radiological Protection, ICPR[6]) in which humans are considered as part of their ecosystems.



In short, the environmental chemistry of radionuclides and radioecology are distinct but complementary approaches that may overlap in some cases in their goal to study the impact of Metallic Trace Radionuclides and their radiation on ecosystems (which may or may not include humans). The main factors under consideration are the radionuclide (its chemical and radiation properties), the object of interest (environmental compartments, biotopes, living species, humans included or not, dose-effect relationships at the individual organism level), and its concentration scale.

Since 2011 at ICN and in collaboration with CEA (Commissariat à l'Energie Atomique) Ile de France, we have focused our research on the study of radionuclides in the marine environment, a key compartment of the hydrosphere. The hydrosphere covers the majority of the earth's surface and is a primary source of biodiversity. It can be defined as the surface on the earth that is occupied by water or ice (and snow). Hence, seawater represents the largest proportion of the hydrosphere (ca. 96.5%) and covers by itself about 71% of the earth's surface. Ice caps, glaciers and permanent snow

are the second compartment with about 1.74% of total water on earth while other sources of fresh water represent only 1.76% of total water. [7] As a consequence, oceans act as a long-term repository for pollutants such as organics, heavy stable metals or radionuclides. Oceans can also be considered as the ultimate receptacle of rivers and catchment areas. In seawater, the accumulation of several heavy metals in marine organisms has been widely studied at all trophic levels. For this reason, the marine environment has often been monitored as a pollution landmark.

Considering this focus on the marine system, our approach certainly deviates from a methodology based on pure inventories, because we are looking for pathways for studying speciation in living systems. This way we are considering Metal Trace Radionuclide contamination in marine species as a complement to current radioecological approaches.

We have considered sentinel marine species of local pollution because of their sedentary habits and well-known sensitivity to pollutants. Possible sentinel marine species that are easily handled at a laboratory scale are sea urchins (echinoderm) or mussels (bivalve). Mussels are for instance the subject of an international program (the Mussel Watch Program) on metallic trace element accumulation. [8] We investigated for instance the biochemical reactions that are responsible for the uptake of some Metal Trace Radionuclides (Nat-U, 60-Co, 137-Cs) with sea urchin *Paracentrotus lividus* using a well-controlled system of aquaria contaminated with the Metal Trace Radionuclides of interest. [9] For Nat-U for instance, using X-ray spectroscopic techniques combined with analytical techniques, we provided evidence of the metabolization of uranium in living *P. lividus*. [10] The accumulation rate of uranium found in the digestive tube is almost 3 times and 10 times higher than in the gonads and the shell and spines, respectively. We have also determined one of the target proteins that could bind uranium within those organs. These data clearly highlight the necessity for speciation investigation in each compartment separately, as the accumulation rate of uranium is radically different between the three compartments.

III Concluding remarks

Ultra-trace levels of contamination in the environment often preclude the use of spectroscopic techniques and the determination of direct speciation data. Heterogeneity at various scales also requires adapting the size of the probe to the size of the sample. This always questions the representativeness of the measurement. Those two limiting conditions (ultra-trace environmental levels on the one hand, and heterogeneity on the other) have up until now formed the bottleneck of speciation studies. In our effort to input speciation data in environmental (and radioecological) metrics, we have developed a methodology consisting of laboratory exposures in a controlled environment that tries to fill this methodological gap. Our recent work on marine species uses this approach which overlaps radioecology and environmental radiochemistry. The major limitation is certainly the validation of representativeness for real contaminated ecosystems. For that purpose, care should be taken to complement such approaches with field data, as much as possible.

In conclusion, obtaining speciation data calls for a methodological compromise. Nevertheless, the input data so gathered is essential and can impact calculation codes developed on a larger scale.

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Reflections on Forest Fires and Floods in a Context of Rapid Climate and Land Cover Changes

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I. How climate and land cover are changing at unprecedented rates

Climate change is the greatest challenge facing societies today and can be described according to three interrelated aspects: progressive temporal trends in temperature and rainfall patterns, changes in short-term weather events, and the cumulative impacts of these two components on ecosystems and societies (Donat et al., 2016). In the context of forest fires and flooding, we expect warmer temperatures will increase the duration of the forest fire season, increase burnt area in warmer and drier conditions, and expand the territorial area susceptible to burn. Rainfall events are expected to become more extreme as warmer air drives greater evaporation and increases the volume of water that can be stored in air masses before dew point temperatures are reached.

Independently of climate change, land cover is undergoing rapid changes at the global scale for demographic and socio-economic reasons. Demographically, it took humans thousands of years to reach a world population of about 1 billion around 1800. Since then, in just 300 years, the population is expected to reach about 10 billion people in 2100. This exponential growth in population has several repercussions, among which we can cite the overexploitation of soil resources leading to irreversible land degradation and the need to clear forested areas, especially in equatorial regions, in order to compensate the loss of agricultural land to soil erosion and urban expansion. As population density increases, subsistence agriculture can no longer meet the needs of a growing population and people migrate to urban centres where economic prospects are better. Human migration is expected to increase as marginal dryland areas become warmer / drier and therefore less life-sustaining.

II. Forest fires

Forest fires have been an intrinsic part of some ecosystems for thousands of years. They have also been a land management tool throughout time in bush clearing practices by shepherds and slash and burn agriculture. Forest fires depend on ignition and propagation dynamics: an initial heat source must first start a fire and then environmental factors, such as temperature, wind speed, and vegetation moisture content and characteristics, determine how fast and far a fire will spread.

Over the past hundred years, human-caused fire ignitions have increased dramatically through infrastructure (power lines), accidental (bush clearing, sparks, cigarettes, etc.), and intentional (gain or conflict) causes. Changes in climate and land cover converge to favour more frequent fire ignitions, and some areas of the globe, most notably Australia, California, and equatorial forests, have seen unprecedented fire seasons in recent years.

III. Post-fire flooding risks

Forest fires have implications for hydrological processes (Shakesby and Doerr, 2006). The combustion of the vegetation and litter layer leave the soil bare and exposed to rainfall, so infiltration rates are typically lower after a fire (Parise and Cannon, 2016). In addition, in some circumstances, organic molecules volatised during the fire can penetrate into the soil, condense, and form hydrophobic surface coatings on minerals. This water-repellent layer can contribute to increase runoff.

Forest fires often occur on upstream forested areas that are less suitable to agriculture or urban development. Frequently, hot dry summer seasons are followed by a rainy fall season, so rainfall events fall on steep bare soils likely to generate high runoff rates. Flooding risk is low in the upland area, but runoff concentrates downstream and poses a serious risk for urban areas in alluvial plains or coastal areas which frequently have high population densities. Flooding risk is therefore greatest where the temporal sequence is a rainy season after a hot dry season and the spatial sequence is a steep forested area upslope of a flatter urban area. This temporal-spatial combination is common in Mediterranean and other environments. During extreme rainfall events, runoff can transport large quantities of coarse sediments, including boulders, which contribute to downstream damage.

IV. The Montecito case study is an iconic event (January 2018)

Montecito is a city in Santa Barbara County, California, USA, that corresponds to the spatial-temporal configuration described above (Fig. 1). In December, 2017, the Thomas fire (one of the largest wildfires in California history) extended from the ridge crest of the Santa Ynez Mountains to approximately the apex of the urbanised alluvial fans upstream of Montecito. Only 20 days later (9 Jan., 2018), the area was subjected to heavy rainfall. The event caused rapid and sudden flows consisting of mud, boulders and tree branches up to about 5 m in height, and moving at estimated speeds of up to about 30 km/h into the downstream creeks, valleys and lower areas of Montecito (Douvinet, 2022).

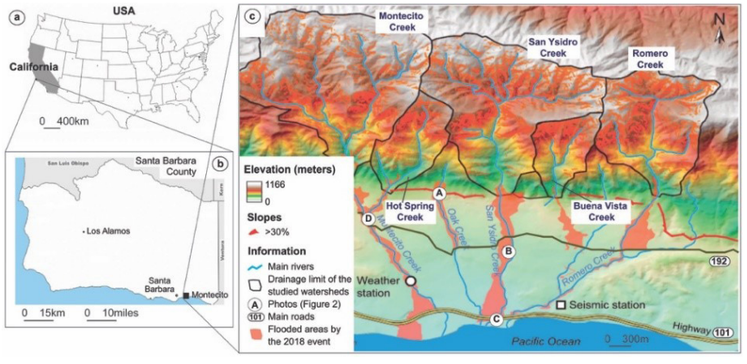

Figure 1. Location of Montecito and impacts of debris flows (adapted from Ciu et al., 2019)

The rainfall threshold for the occurrence of debris flows decreased substantially due to the high percentage of burned area in the upper catchment: this ranged from 49% within the Hit Spring Creek to 85% in San Ysidro Creek (Douvinet et al., 2020). Human, economic and environmental impacts were severe (Fig. 2). The flooding and torrential flow of boulders, mud and debris caused 21 deaths (and 2 missing persons), and 163 people were hospitalised for injuries. At least 408 homes were destroyed or damaged, and 92 structures were completely destroyed; and an additional 163 structures suffered damage. Although creeks were incised by more than 5 m into the surrounding terrain, the debris flows overflowed the valleys, often at bridge crossings, and carried boulders into neighbouring residential areas. Debris flow deposits covered around 7 km^2 and the cumulative amount of sediment ranged from 297,000 m^3 to up to 880,000 m^3.

Fortunately, before the 2018 event, Montecito had a high level of situational awareness of the risks of post-fire flooding and debris flows due to previous events (Fig. 2). Historically damaging debris flows (1914, 1926, 1934, 1964, 1969, 1971, 1990, 2002) had been recorded, and debris-flow research had been ongoing since the 1934 debris flow in Montrose that killed over 40 people. Risk awareness was demonstrated by coordinated efforts between county, state and federal agencies that included: (1) the determination of fire burn severity as a good indicator of flooding and debris-flow potential; (2) a debris-flow hazard assessment that showed a high likelihood and potential volume of debris flows from the burned areas; 3) a warning system that predicted significant to extreme potential for debris flow in the four days leading up to the storm; and (4) a proactive emergency community that coordinated evacuation orders to reduced casualties. This post-fire planning reduced the number of casualties substantially.

Date of the debris flows: 9 Jan., 2018
Wildfire: Thomas Fire
Time between fire and rainfall: 33 days
Damage: 21 deaths, 2 missing, 163 hospitalisations, 330 evacuations, 1300 emergency interventions

Date of the debris flows: 25 Jan. and 18 Feb., 1914
Wildfire: Sycamore Canyon Fire
Time between fire and rainfall: 5 months
Damage: 5 deaths, more than 25 relocations

Figure 2. Impacts after the 2018 (left) and the 1914 (right) debris flows in Montecito

V. Concluding remarks

As the climate continues to change, events like the Montecito disaster and other recent similar events are expected to become more frequent. Typically, in the spring, soil moisture and warming temperatures favour vegetation regrowth, so the risk of flooding tends to decrease exponentially the first year after a large fire. The case study demonstrates the importance of crisis management preparedness. The time window between a large summer fire and intense fall storm is short, typically ranging from weeks to a few of months. Within this time frame, local authorities must quantify the risk, map the most vulnerable areas, install mitigation structures (check dams, retention basins, etc.), and prepare an evacuation strategy that can be implemented quickly and effectively when weather forecasts require. Research is needed to optimise these steps in post-fire flood management preparedness using satellite imagery, hydrological/hydraulic modelling, and organisational command chains in a multi-disciplinary approach.

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Why is (bio)diversity so important?

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The concept of biodiversity was highlighted at the Rio Conference in 1992 and is defined as the biological diversity of all living organisms on Earth and at all levels, from genes to ecosystems. Biodiversity can be observed/studied at three levels: ecological diversity (ecosystems), specific diversity (species) and genetic diversity (genes).

Biodiversity is the basis for the functioning of all ecosystems on Earth. These ecosystems provide a large number of services such as climate regulation, cleaning of drinking water, air purification, pollination of crops, soil fertilisation and providing of medicines (Brondizio, E.S. et al., 2019). High biodiversity keeps ecosystems healthy and helps humans stay healthy as well (One Health concept). Biodiversity is also an essential part of the solution to climate change and is therefore good for the economy: at least 40 percent of the world's economy is derived from biological resources.

When we impact biodiversity through all sorts of human actions, we ultimately damage ecosystems, and therefore all ecosystem services. Damaged ecosystems are more fragile and they have limited capacity to cope with extreme events. We need to maintain well-balanced and healthy ecosystems, which protect us against unforeseen disasters, the emergence of new diseases and often offer us solutions to the most urgent and complex challenges.

It's all about balance! All living organisms are interdependent on each other for their survival. In other words, every species on Earth contributes in some way to the functioning of the overall ecosystem. If one species disappears, this role is no longer assured and the overall functioning of the ecosystem is disrupted, sometimes with dramatic repercussions. There are many examples of loss of diversity.

Take the case of insects, which are the most diverse group of organisms, with several million species. Everyone complains about the nasty mosquitoes that carry pathogens, or the voracious caterpillars that ravage maize crops, etc., but actually only 1% of insects are crop pests, whereas insects provide many services, such as pollinating crops, recycling organic matter, controlling other pests and balancing food chains. Estimates of the loss of insect species range from 50% to 75%, which is considerable (Jactel H. et al., 2020). The main causes of the extinction of these insect species are the destruction of their habitat, the massive use of pesticides (insecticides), climate change and invasive species. For example, the disappearance of some insect species can have a very significant impact on pollination and plant growth and therefore on crop yields. In addition, the disappearance of insect species leads to a decline in their predators: many bird and bat species are affected, just as fish species are affected by the disappearance of aquatic insects. Conversely, if certain species of dragonflies (which feed on aquatic mosquito larvae) disappear because of poor water quality (pollution), then mosquito populations will flourish!

Let's dive into the sea... the ocean is responsible for 50% of primary production on Earth, sustaining our food system. However, rising nutrient loads coupled with climate change, each resulting from human activities, are increasing oxygen consumption by changing ocean biogeochemistry (Breitburg D. et al., 2018; Gattuso J.P. et al, 2021). Deoxygenation of coastal sites will affect biodiversity and food webs and may result in ecosystem collapses, which ultimately will affect food security and livelihoods of the people who depend on it.

The diversity of organisms in seawater is huge and we are only starting to understand the biotic interactions among grazers, primary producers, viruses, and symbionts (mainly parasitic). In every millilitre of seawater, there are 10 to 100 billion microorganisms and viruses. While the major role of these organisms in biogeochemical processes is well known, the interactions between species and the role of viruses are less documented and remain to be discovered. As part of the Tara Oceans project, the associations and interactions among planktonic organisms was studied and provided a resource to support further research on ocean food webs (Lima-Mendez G et al., 2015). The role of viruses and parasites is often beneficial to the ecosystem. For example, unicellular parasites can multiply rapidly to control blooms of toxic dinoflagellates that are a threat to marine ecosystems, and thus help maintain a healthy ecosystem (Chambouvet A. et al., 2008). The functioning of oceanic microbial communities is comparable to that of microbial communities in the human digestive system.

Thus, these examples illustrate perfectly that each species is important to preserve. We should not only focus on emblematic or patrimonial species (e.g. whales), but every link in the chain counts (preserving krill, the plankton that whales feed on).

Similarly, actions to conserve Posidonia oceanica, a marine plant endemic to the Mediterranean sea, are useful if they do not damage adjacent habitats: the development of anchoring systems outside the sea grass beds, which act as a nursery for many animal species, is of great interest, but these anchoring systems have also to be installed outside the adjacent soft-sediment habitats, which are certainly less emblematic, but whose ecological role is just as crucial! The sand habitats serve as a refuge for a rich and exceptional fauna. These soft-sediment ecosystems are indispensable because the organisms that they host are themselves linked to the trophic chain of larger predators (fishes and marine vertebrates).

And because we are inclined to better protect what we know well, the first action must be education, if possible from a young age. We must explain the importance of maintaining the diversity of organisms and promote the conservation of all species, from the seahorse to the jellyfish!

Finally, the importance of diversity must also be found at the level of institutions and organisations: promoting diversity in terms of gender, culture and origin is a way of resolving the main challenges and therefore of moving the collective forward!

A bit like the moral of La Fontaine's fable "The Lion and the Rat", which says that you always need someone smaller (or different) than you. ☺

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Target 13.2
Integrate climate change measures into national policies, strategies and planning.

Energy management, mobility, carbon footprint, holistic approach and social justice

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I. Foreword

Our presence here is a clear sign that we do agree on the fact that we are going to face the most challenging and endangering situation ever encountered by the human race, and, more generally, all living species will have to address conditions (and possibly suffer consequences) that have not occurred in geological time. For the sake of clarity, and to briefly summarise, not only must we drastically reduce our greenhouse gas emissions (GHG), but we also have to consider likewise decreasing our consumptions of numerous natural resources: biotic, such as fishes and natural ecosystems (forests, wetland, etc.), or abiotic, like minerals and lands.

As a first key point, let us point out a simple fact: we must decrease all our environmental impacts, beginning first and obviously with our GHG emissions.

This being said, it is also worth recalling that this dependency on fossil energy was not completely unjustified and inefficient. In two centuries, welfare and health have singularly increased in all countries, even if inequalities still exist; nowadays, the quality of life has achieved very high levels in many countries. Such a result should be kept, and extended to all humankind, so as to permit to every human being access to the same services and standards available in the richest countries. In other words, the aforementioned recognised, incontrovertible and necessary decrease shall not jeopardize the legitimate aspiration of billions of people for a better life, as recalled by the sustainable development goals (SDGs), and for tens of countries for a higher human development index (HDI).

In this paradoxical race, it is clear that we are facing two contradictory injunctions. Indeed, the observed benefits rely on an economy that was, and is still, extremely dependent on fossil fuels, but we must restrict and quickly reduce their use. However, keeping a strong economy is important for two reasons. First, the economy will be the pillar on which our life standards will be maintained and secured: a weak economy would seriously curtail our abilities to build a sustainable future. Second, our recent past has shown that economic issues can easily lead to tumultuous social climates: this fosters the development of populism, almost invariably against any (environmentally friendly) actions. Practically, this creates the impetus for the development of new basis of and for economy, still eliciting a pleasurable life but in a healthier environment.

Consequently, we must engage a mid-term transition to change our economic paradigm without endangering it, to keep levers for action, but undeniably towards a more decarbonised structure.

Last but not least, one final critical point will be to warn against too much confidence in technology-only solutions, and paying too much attention to technological siren songs. As a physicist and expert in the energy field, I will put forward in this advocacy some proposals in this direction. Nonetheless, the task being so huge, it is illusory to think that technological solutions will be sufficient alone. There are many reasons for such a statement. First, the ever increasing demand cannot reasonably be fulfilled if we continue apace with the current trends (and here again, not solely for fossil fuels). Second, taking the example of energy only, many studies and official reports from several governments (France, EU, etc.) have shown that renewable generation as it is currently promoted (i.e., mainly relying on photovoltaics and wind) will not be sustained easily in the future due to lack of some minerals. Third, the rebound effect or some other cognitive bias (e.g., unrealistic optimism), usually leads to smaller reduction or change than initially anticipated from a physical point of view. Fourth, it will be very difficult to create the impetus for a sustainable world, and to efficiently engage people in the struggle for decarbonation (and equivalent measures), by proposing only some technologies. Local features such as the weather, the population density, the organisation of the energy networks must be considered; as well as the use and habits, traditions and cultures, social organisations, etc.

Briefly, the last message is therefore to emphasise the need to combine natural sciences and social sciences in our search for this new world organisation (briefly represented by the triptych consumption – economy – sustainable development). There will not be a single solution, and these solutions will not succeed if they are not developed and fostered by a holistic approach.

II. Proposals

First and foremost, the main issue we are facing is due to our energy demand. When looking physically at its corresponding nature, it is interesting to note that it can basically be divided into electricity, heating and cooling. Given this observation, the first proposal is to better promote multi-energy networks and poly-generation systems, to avoid an unjustified concentration on electricity. For instance, relying only on photovoltaics is not a good idea when heat is required (even if a heat-pump can help to achieve better efficiencies) and solar thermal should be considered (when and if feasible), or biomass burners. Practically, this could be done by modifying regulations and through incentive funding for such systems and networks combining various energy forms, and by favouring technical solutions that better suit the real needs.

Secondly, it has been mentioned the level of consumption is too high and, though renewable generation must be increased, it is also important to make better use of energy. Technical solutions that allow us to decrease the demand, such as energy efficiency and demand-side-management (among others), should therefore be further deployed. Here again, this deployment should be supported financially.

Thirdly, it is important to keep in mind that the underlying goal of the former proposals is to achieve a strong decrease in our GHG emissions. Consequently, this means that a thorough analysis of these latter must be undertaken. Concretely, any public investment should be subject to carbon neutrality, or at least physical proof that GHG emissions are limited to minimal values. As an example, the

absence of any carbon footprint balance should be forbidden. In the future, such measures should also be linked to performance-based contracts to ensure that GHG reductions are attained. For instance, thermal building renovation should be more controlled to guarantee an optimal use of the committed money.

Finally, the emphasis has been put on not relying only on technological solutions. In this respect, it is mandatory to consider trans-disciplinary approaches in all the above proposals. Social sciences must be combined with physical sciences to ensure a better application of the induced changes, and to limit the risk of rebound effects, or any negative or vicious spiral counter-effects. Without any loss of generality and non-exhaustively, environmental psychology and sociology, economics and law should be considered, at least. To be more precise, part of the granted funding should be devoted to addressing the challenges with these viewpoints, and/or transverse approaches should be favoured over siloed ones. In fact, and remaining only on a pragmatic point of view, a better adherence could also be achieved by involving culture and arts, and so, some trials could be tested in this way (and quantified, on an energy efficiency basis).

The second main contribution will concern the mobility issue. Indeed, it is clear that in the short to mid term, freight of goods and merchandise will not vanish and so they will play a significant role in GHG emissions. In spite of needed tests and trials of new solutions in this specific field, more intense efforts should be focussed on the mobility of people. Without hampering the substitution of thermal vehicles by electrical ones, it is also noteworthy that the latter cannot simply replace the former. Indeed, the forthcoming scarcity of some resources, and the environmental impacts associated with this sector, do not play in favour of a massive penetration of such technologies. There could be two rather simple solutions to such an issue. Firstly, the main need being for short travel and to promote soft mobility, light cars with limited speed should be asked of manufacturers. In addition, vehicle sharing should be further developed through incentives and dedicated regulations (e.g., reserved parking lots or recharging slots). At the same time, the key role of intermodality must be further scrutinised, since real beneficial reductions can be achieved without any restriction on the travel possibilities. Pertaining to intermodality, the steps to release it more freely are three-fold: i) better physical interconnections, at various locations and for different distances, with reinforced regularity and (more importantly) secure first- and last-scheduled train/bus/etc. ; ii) incentives and ambitious sponsored tariffs such as, for example, similar investments as in renewable energy and/or thermal insulation for partially or totally reimbursed yearly subscription fees; iii) better coordination between all stakeholders with simple tools for customers to find and book their travel and trips (e.g., centralized web platform, dedicated app, SaaS solution, etc.).

Logically, these solutions should once again not be primarily and uniquely based on the technological features. In contrast, it is mandatory here to undergo social sciences analysis, with the help for instance of geographers and experts in spatial planning.

The third and last proposal based on an engineering and physics approach will concern the products and goods with a high carbon footprint. Though our society could sometimes legitimately question the needs for some of them, a simple practical analysis is performed here. As such, the first and efficient signal sent to the customers would be the generalisation of carbon labels, and the obligation to provide an estimation of the whole carbon footprint of any products, goods and even services. Furthermore, the impacts being possibly huge, a stronger emphasis must be put on the repairability index with i) the gradual enforcement of a lower threshold, and ii) the development in parallel of local sectors (supported by jobs and SME, and not associations only). In this regard, low-tech sectors and circular economy must clearly be singularly more investigated, supported and disseminated.

Finally, this contribution will end with two major remarks to shed a light on the general consistency of the whole approach and the solutions proposed above.

Whatever the solutions tested and the choices finally made, it is above all vital to try not to create the conditions for a similar disaster in twenty or fifty years. More precisely, in this race for decarbonation, we also must keep an eye on the other planet boundaries and similar vulnerability points. A specific attention should thus be given to controlling and limiting the environmental impacts, as specified by life cycle assessment for instance, but also to biodiversity (in all its forms). If we are to have some success against climate change, it will not come without high burdens and painstaking efforts: may this effort not be partially wasted by the destruction of other features that are as important as the climate for humanity.

Furthermore, tremendous work has been undertaken (or is to be) by all humankind, and deep and persistent modifications of our way of life are ongoing. In such a context, it is compulsory to ensure that laws are respected. In fact, this is not strictly a call for more severe regulations (even if one could advocate in this direction, yet they will certainly come in time) but to enforce the existing laws and to have fines that really discourage fraud. This is highly important for four reasons: i) targeted reductions cannot be achieved when fraud is present, which undermines our efforts against climate change; ii) cheaters must not earn more than serious players and court sentences must therefore be really dissuasive; iii) equivalent to the most serious felonies, strong sanctions and severe penalties do send the message that such behaviours are not acceptable any more and must be modified; and iv) it is both a question of social justice and of equity between everybody, which strengthens social acceptance and reinforces overall engagement.

Urban mobility in the Principality of Monaco. Adaptation and behaviour change as a response to the climate crisis.

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Introduction

Urban mobility is one of the central issues pertaining to climate change as it directly affects public health and quality of air. In 2013, the European Commission proposed Guidelines (Wefering et al. 2013) on Sustainable Urban Mobility Plans (SUMPs). Most of the measures outlined have been implemented in European cities (Pisoni et al. 2019), cases of which have been analysed throughout the world highlighting the possibilities, benefits and limitations of the guidelines. For instance, the review of SUMPs developed in Portugal (Arsenio, Martens et Di Ciommo 2016) found that SUMPs mostly concentrate on meeting people's immediate mobility needs and overlook climate targets. In most public policies, societal concerns such as accessibility, overall public adoptability, and economic sustainability are the predominant focus areas (Vecchio, Porreca et Jácome Rivera 2020). In the framework of our PhD research on Monegasque culture and sense of belonging, we present an overview on existing practices of urban mobility in Monaco through the lens of urban anthropology. Adaptation and changes in mobility practices in Monaco are therefore not only sociological factors (of the consumer's behaviour), but anthropological features of a specific strategy of social behaviour. The methodological approach combines the review of governmental actions, immersive participant observation, as well as qualitative analysis of stakeholder communication. The central question we aim to answer is "To what extent can a given population's behavioural culture contribute to the successful implementation of a mobility plan?"

Social behaviour of Monaco inhabitants: theoretical pitfalls and literature review

This analysis is inspired by the theory of symbolic interaction (Goffman 1959). The dramaturgical approach suggests that social action depends on how people present themselves on the social stage. Moreover, Goffman's work appears relevant as his theory has been applied successfully in studies of «closed» communities in the context of broad modern societies. The empirical data we have received so far indicates that residents of the border areas view Monaco as a rather closed community.

The difficulty herein lies in assigning a unique behavioural culture to the multi-national principality of Monaco. Culture itself can possess an arbitrarily broad meaning. Were we to try and condense and isolate cultural patterns -– at this stage –we would limit ourselves to the concept of "common sense" – meanings that various layers of society agree with. One such "common sense" that unites the majority of inhabitants, is the practice of publicly endorsing the Prince (despite the fact that in private conversations people may have diverse opinions). One of the deepest concerns of Prince Albert II is climate change.

As one of our respondents, Monegasque, 59 years old says:

«Monegasques are loyal to the Prince. We trust the Prince and if the Prince asks for something, we work on it. In addition, we are making ourselves stupid because the subject (climate change) is really very legitimate, huh. Maybe individually, we might would not have done so much. But the fact that the Prince asks, we are obliged. It's not something as if the inhabitants are tyrannized, not at all! It's common sense. The will of the Sovereign is carried out by the Monegasques. It's something natural, not an effort.»

General overview of governmental plan on public urban mobility

The display of an approved social behaviour in Monaco (collective determination) is facilitated by the broad range of opportunities provided by state structures (individual choice facilitation) (Thevenot 1991), which implement programs inspired by the Prince's concerns.

The urban parking network offers several solutions: since 2010, users have been given 10% discount on the parking monthly subscription, if a given parking space is used less than 15 times in a calendar month; then the subscriber's magnetic parking card can also serve as an unlimited free bus pass. Eight out of 10 respondents stated that this measure allows them to almost completely avoid using a car within the city.

The decision to take a bus is facilitated by the fact that an updated fleet (22 hybrid buses plus 10 modern electric buses added in 2022) covers various high-intensity routes on seven main lines, including the night bus. The waiting time rarely exceeds 5 minutes. Buses represent an opportunity to nourish one's feelings of belonging: the rules of social interaction in buses are visibly more particular than those around the Principality.

In October and November 2022, Monaco is testing free bus travel for all. The purpose of the test is to see how much the automobile traffic is reduced. This measure could generate a direct impact on the pollution level. The service users are targeted by an extensive marketing campaign: "practical and responsible solution" for the active people category; "ecological and economic" for young people; "in serenity" for the older generation.

To encourage switching to electric automobiles, the Principality offers 53 electric car charging stations free of charge. For the hybrid engines, one recharge guarantees a range of 40-50 km, equivalent in fuel to 10 euros saved. For the electric cars, a range of 200-300 km saves around 50-60 euros. The parking rate goes down by 20 euros a month for those drivers with electric vehicles who subscribe to Monaco Parkings. The national Monaco statistics bureau, IMSEE, reports that in 2017 the number of electric cars corresponded to 842. This figure has risen to 2572 for the year 2021; as for hybrid engines, they have increased from 867 (2017) to 2606 (in 2021).

Mobee is an electric vehicle car-sharing service. The vehicle is geolocatable via a smartphone application and can be picked up or released anywhere in the Principality (Twizy), and in certain closed- loop car parks (e208). The number of cars at the population's disposal has doubled from 2017 to 2021; the number of service users has increased from 375 to 1,595; as has the number of km

– from 60,784 to 233,713 respectively.
The government finances more than 2,000 carpool journeys (15,000 people per week) for those workers hailing from either across the Italian border or from neighbouring French towns and who use the Klaxit mobile application. Nearly one million kilometres have been travelled and 160 tonnes of CO2 saved thanks to this scheme.
To optimise delivery services, the government has set up a mobile application to check availability in the connected delivery areas.

A new public parking lot is set to open in 2023 at the west entrance into Monaco. With a capacity of welcoming 1820 vehicles, the expectation is that tourists and workers alike will park there and use complimentary public transport to travel into Monaco. According to our survey of Parking subscribers (for whom buses are already free of charge), this measure shows considerable change in urban mobility behaviour.
The Principality has set up 35 "Monabike" stations with 350 electric bicycles available to all for an hourly fee. Figures show the population has embraced this alternative means of transport. In September 2022 a "Monabike" station was set up in the border-town of Beausoleil. By the end of 2022 there should be an additional three such stations.
Municipal elevators and escalators strongly incentivize walking in Monaco on foot, as one can avoid both stairs or slopes. This is an illustration of a limited territory paradoxically turning into an advantage. In 2021, Monaco counted 87 elevators working around the clock, an increase of 9 on the previous year. Additionally, eight outdoor escalators have been extended to downtown Beausoleil (with the principality financing just under half of the costs), thus providing an alternative means of transport, green and free of charge.

Measurement of results and further challenges

H.S.H Prince Albert II is a strong generator of sustainable actions, which are then implemented to the maximum extent within the framework of various governmental programs. These initiatives are vigorously supported by the inhabitants: a growing number of people are switching to buses, choosing to reach their destination on foot, by bike or using car-sharing solutions. People are switching to electric, or abandoning their own cars altogether as more practical, economical and environmentally friendly measures are available. Such conscious actions remain a behavioural norm and common sense in Monaco. Showing visible markers of endorsement and respect for the Prince's initiatives enables fulfilling one's social function when meeting others, allowing one to define oneself as a responsible person who cares about the environment as a legitimate subject. International residents of the Principality are frequently participating in this common sense – which represents an opportunity to acquire the feelings of belonging, as shown in the results of our interviews.
According to the National Inventory Report, between 1990 and 2020, the Principality of Monaco's greenhouse gas decreased by 31.8%, the transport sectors seeing declines of 17%. But despite these intermediate results, most of the respondents are inclined to believe the problem of reducing vehicles in the Principality is still relevant. In addition to having around 40,000 daily commuters into Monaco, traffic management and green mobility initiatives and efforts are constantly reduced by tourist flows. The population is somewhat heterogenous, with Monegasque citizens a minority (22.5% or 9,611 people) against 77.5% (39,150 people) international residents, although these two social strata show some intersection. However the majority of Monaco inhabitants and visitors to the Principality represent two spheres of society with rather limited intersection. This raises the following question: can the wider involvement of tourist masses in this "common sense" contribute to further progress? In order to answer this question, we suggest further research.
One of the solutions might be a strong promotion of the "Monegasque way of life". By buying into this sentiment, any given person will have the opportunity to better represent him/herself on the social stage and, therefore, to acquire a sense of belonging. We understand that the issue of choosing the mode of mobility is much broader one which deserves exploring. In this article we have chosen to present one of the non-obvious possible drivers of choice.

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Target 13.3
Build knowledge and capacity to meet climate change

ABSolEU - Paving the way for an ABS recycling revolution in the EU

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In the core of UN efforts for the fight against climate change is multilateral cooperation. This principle is enshrined also in the ABSolEU project, which is an initiative funded under the EU's Horizon Europe Programme. It is simultaneously a multilateral collaboration that aims to pave the way to circularity for the ubiquitous plastic ABS, found in durable products from toys and other consumer goods to automotive components, and therefore revolutionise the current state of the art of ABS recycling in Europe and beyond.

ABS is not a single-use plastic. On the contrary, in the world of plastics it can be considered as one of the most durable. ABS is a complex material made of three components:

- A = Acrylonitrile ▶ provides thermal and chemical stability
- B = Butadiene ▶ provides toughness and strength
- S = Styrene ▶ gives the glossy finish

ABS plastic is specifically designed with long-lasting products in mind and is therefore able to withstand long and intense use phases. The proportions of the components (A, B and S) can vary and are adapted according to the properties desired in the resulting ABS. For instance, the composition, the nature of additives and the processing will vary significantly between toys (e.g., Lego bricks), automotive parts and electronic equipment.

As a thermoplastic, ABS can in theory be fully recycled. But the fact that ABS can have different grades and compositions, due to altering the degree of each component, can make recycling difficult. Recycling efforts are moreover often hampered by the presence of additives and fillers. The uncertainty around the presence of such undesirable substances, as well as the difficulty in removing, them generates problems regarding the purity and quality of the resulting secondary plastics. This raises health and safety concerns that limit the reuse of secondary ABS plastics for certain applications. It would be problematic indeed if ABS wastes from old electric and electronic equipment (containing additives such as flame retardant) are recycled into ABS products for children's toys. In combination with the fact that recycled ABS, like many plastics, loses quality and performance over time, the end-of-life scenario for ABS products is in 85 % of cases landfill or incineration. Only a marginal quantity of ABS from consumer electronics and appliances is today collected, mechanically recycled and sold again for consumer applications. The quality of these streams is also difficult to control, due to the heterogeneous composition of ABS resulting from the diversity of applications and grades applied to such products, and the concerns about harmful additives prevail.

The ABSolEU project is led by Université Côte d'Azur and in particular the Nice Institute of Chemistry, along with the contributions of GREDEG and CNRS. The consortium brings together 10 additional partners, namely LEGO, BIC, Volvo Cars, TRINSEO, TNO, RI.SE, GALOO Plastics, Swedish Institute of Standards, JOTNE and Prospex Institute. Thus, it is implemented by a robust consortium that spans the entire ABS value chain, as it comprises 3 global – and iconic – brand owners, 2 RTOs, an ABS-producing company, a recycler, a traceability solutions company, a standardization institute and a company specialised in stakeholder engagement.

With ABSolEU, the consortium is seeking to lay the first bricks of a sustainable future for ABS plastics. The overarching ambition of ABSolEU is to revolutionise the current state of the art of ABS recycling. Concretely, ABSolEU will realize this ambition through a dual approach of demonstrating technological innovations for ABS recycling, while establishing a supportive framework for the diffusion of the innovative efforts of the project, with the aim of improving methods and standards for characterisation, traceability, and quality assurance of rABS products.

In particular, the ABSolEU project will develop and mature an innovative technology for the physical recycling of waste ABS, providing clean and safe recyclates that are free of additives and contaminants, i.e., ready to be reintroduced into the value chain for high performance products. In addition, project partners will develop new analytical methods for safety and quality assurance, raising awareness about the composition of ABS waste streams, and will provide the scaffolding to support the adoption of physical recycling for ABS and the uptake of ABS recyclates by industry and consumers. To this end, it is expected that by the end of the project they will be able to lay the first bricks of a sustainable future for ABS plastics in Europe and beyond.

The ambition of ABSolEU project is reflected in its six objectives. ABSolEU partners will work towards establishing conditions for a transition to a system where the value of ABS, as material and product, is retained throughout the product lifecycle, delivering economic and environmental benefits – thus paving the way to an increased share of recycled plastics in added value products. The ABSolEU objectives are the following:

- Engage with value chain stakeholders, citizens, and policy makers
- Develop and scale up a physical recycling technology capable of eliminating hazardous substances from the ABS waste stream
- Establish analytical methods to guarantee the safety and quality of ABS recyclates
- Explore and propose traceability systems for ABS products
- Diffuse innovation throughout the ABS value chain
- Promote a supportive framework for ABS recycling through standardisation

Finally, ABSolEU is in line with the 2030 Agenda for Sustainable Development, adopted by the UN Member States in 2015. In particular, the tasks and activities of the project aim to contribute directly to the following Sustainable Development Goals (SDGs):

SDG 9, by contributing to the development of resilient infrastructure of plastic production and reuse, promote inclusive and sustainable industrialization and foster innovation around plastic.

SDG12, by working for the development of innovative and sustainable consumption and production patterns for ABS plastics.

SDG13, by taking urgent action to combat climate change and its impacts through its methodology for plastic waste management, treatment and recycling.
ABSolEU indirectly contributes to SDGs 4 and 17, as it will raise awareness among the academic and scientific communities about ABS plastic recycling, and the products generated within the project's timeline will constitute valuable educational materials that could be used by academic institutions and research centres in Europe and beyond, reinforcing education; at the same time it constitutes a global partnership that focuses on a multi-stakeholder approach and the promotion of sciences and technology.

7 AFFORDABLE AND CLEAN ENERGY

Assessing the perception of nuclear risk

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I. Introduction[1]

In an effort to reduce carbon dioxide emissions, many countries throughout the world are initiating plans to transition to more sustainable forms of energy. Nuclear energy would appear to be a powerful contender to replace fossil fuels, or at least an unavoidable option, from an energy-mix perspective. However, nuclear energy suffers often from a poor image among certain populations, who may prefer to favor the development of renewable energies. Today in France, 56 reactors are in operation, 1 under construction (EPR Flamanville), 1 to be decomissioned (Fessenheim) and the proportion of nuclear-derived electricity was 70.6% in 2019. [2] Worldwide, at the end of 2018, 450 reactors were in operation, and nuclear power accounted for about 10% of global electricity generation, while total electricity generation increased by 2.8% in 2018 from nuclear power. [3]
At the same time, the significant development of the civil nuclear industry in the Northern Hemisphere has raised new questions in terms of environmental impact, long-term management, defence and non-proliferation. Moreover, whether it is being used as a source of energy or for other applications, it is subject to controversy: Nuclear energy tends to feed phantasmagories, fears and the most diverse and varied conspiracy theories. [4] However, among the various sources of electricity production, coal remains dominant despite significant growth in natural gas production. The Chernobyl accident in April 1986, and more recently that of Fukushima Dai-ichi in March 2011, has had a major impact in terms of energy policy in various countries, mainly Western, because of the decline of the social acceptance of civilian nuclear energy. These social concerns, the perception of the public, and industrial development thus raise fundamental scientific, technical and sociological questions.

II. Public risk perception

Perception studies have sought to «determine how the public assesses the risks in order to understand, for example, the differences observed in the positioning of the various social groups», and link «perceptions to attitudes and behaviours", and to move from «perceived reality» to an «objective reality.4 In France, the Institute for Nuclear Radioprotection and Safety (IRSN) has, since

1977, studied the perception of risks with the assistance of the Commission of the European Union. Since then, IRSN has conducted a study based on a questionnaire entitled «Barometer on the perception of risks and security» (Baromètre IRSN, 2018). [5] It is not possible to entirely recapitulate the questions asked in this barometer, since it has been published annually in this form since 1990 and it «traces the evolutions of the opinion of the French people on the social, environmental and technological risks».5

At Université Côte d'Azur (UCA) we have setup a survey, composed of multiple choice questions, supported by the Limesurvey Internet platform. This survey had the three following characteristics: it was «instantaneous», in the sense that it provided a snapshot, at a precise moment, of the perception and knowledge of nuclear energy in France; it was «atomic»,[6] because it aimed for each individual surveyed to understand how he or she received information on nuclear energy (e.g. very trustful, trustful, not very trustful, not at all trustful, etc.); it was also «contextual», since this questionnaire made it possible to observe the perception and the knowledge of the individuals according to whether they were socially and individually identified as an expert or non-expert.

Two homogeneous groups of individuals formed the population subgroups to respond to the evaluation criteria on information about nuclear energy according to their level of expertise. The first group was that of firefighters, who constituted the expert group. The second group was that of students of UCA, who constituted the non-expert group. These two groups were of relatively uniform size, with 1240 and 1075 surveyed individuals, respectively. [7] These two populations are not the most extreme in terms of profiles, indeed we could have interviewed nuclear actors and compared their opinion with those of the students, or general public. Instead, we preferred to consider the firefighters, who have some knowledge by their training but who do not depend on the nuclear industry, with those of the students. In view of the different analyses, we can say that the two populations (students, firefighters) have a rather different perception of nuclear risk, which is largely explained by the knowledge acquired by firefighters in this area through their training, and by the fact that they are mostly older than the students, they grew up with nuclear energy. In the same way, differences exist according to the field of study for the students (literary/scientific).

Perception surveys by population category shed additional light on studies conducted in the general population. They can lead to new information or even prevention messages that are targeted depending on the group. It would be particularly interesting to conduct a simultaneous comparison between different countries and populations. Of further interest is «understanding why some within the public support nuclear energy, and why others do not, [because it] is an important step toward navigating the divide between the experts and public».[8] [9] Indeed, the landscape of beliefs about local nuclear power should not be viewed in simplistic bipolar terms). According to Stoutenborough «Risk perceptions differ from general attitudes like support or non endorsement because they require a better understanding of the issue than general attitudes». In fact, «the complexities of nuclear power suggest that attitudes cannot be easily summarised in terms of partisanship and/or political ideology». The lack of information and more accurate knowledge on nuclear energy for the population in general, and nuclear risk in particular, has an influence on individual's perceptions, while we know that improved knowledge leads overall to a better acceptance of this form of energy. The main objective was to understand the differences of perception between the expert and non-expert population on the controversial nuclear issue, and on which aspects these differences could be the most important. But we cannot deny that the act of questioning people on the subject of nuclear power may be inherently biased due to the very nature of the subject and that fears surround it are often stigmatised.

III. The management of risks

Public risk perception about nuclear energy also depends on the capacity of operating companies to be safe and reliable. Despite considerable efforts to increase organisational reliability, the nuclear energy sector has experienced major disasters in recent years. Following the analysis of these tragic accidents, safety management increasingly integrates the notion of uncertainty and focuses on the roles played by human and organisational factors. Safety is therefore considered an emergent property of a complex system. [10] A growing number of studies at the intersection of safety and organisational fields highlights the need for dealing with both foreseen and unforeseen events. [11] Organisations perceive and respond to uncertainty by trying to diminish it (reducing freedom and standardising) or by attempting to deal with it (maximising freedom and enhancing competencies to deal with complex tasks). [12] The tension among approaches for dealing with foreseen and unforeseen events crystallises in two forms of organisational safety: regulated and managed safety. While regulated safety relies on technical and procedural barriers to cope with predictable or foreseeable events and is aimed at reducing uncertainty, managed safety aims to develop organisational capabilities to proactively deal with unpredictable events, and thus deal with uncertainty. Research on high reliability organisations and resilience shows that only a mutual reinforcement of these two forms of safety can ensure reliability and resilience. However, research also shows that the intensive development of one of these forms of safety can jeopardise the development of the other form. [13] Thus, a joint development of regulated and managed safety remains a major challenge, which has not yet been fully studied.

At Université Côte d'Azur (UCA), we have developed research to explore the process of the joint development of regulated and managed safety and its mechanisms. [14] It identifies the safety management mechanisms on which this joint development relies, that is, managerial control and coordination, mindfulness, and deliberate learning. Specifically, this research reveals possible negative effects of managerial control, suggest the presence of organisational limits and the dangers of exceeding them. This research also explores the role of leadership for safety for a joint development of regulated and managed safety. This focus on leadership for safety is in line with the preoccupations of the nuclear industry actors. Therefore, Université Côte d'Azur leads a European Leadership for Safety (ELSE) project, funded by the European Union through its Instrument for Nuclear Safety Cooperation (INSC) in cooperation with International Atomic Energy Agency (IAEA). The ELSE project's aim is to develop an innovative research-based approach to advanced education in the domain of leadership for safety, bringing together the most up-to-date academic knowledge and professional expertise. [15]

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8 DECENT WORK AND ECONOMIC GROWTH

Business Model Innovation for Impact: A methodology

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While there has been a growing awareness among businesses of the critical importance of business model innovation (alongside other more traditional forms of innovation), the critical challenges currently facing humanity (e.g. climate change, pandemics) and the strong desire for change among the younger generations (e.g. 'Un manifeste pour un réveil écologique') have led an increasing number of businesses to consider the question of their global impact and search for manners to reconcile economic performance and environmental (Carvalho et al., 2014; León et al., 2019) and social (Acosta et al., 2014; Carvalho et al., 2014) impact through business model innovation (Rangan et al., 2012).

While the issue of business model innovation is very popular in the academic literature, so far few of these works have addressed the question of the relationship between business model innovation and socio-environmental impact. A further issue is that, while the literature provides numerous frameworks for business model innovation (e.g. Joyce & Paquin, 2016; Nosratabadi et al., 2019), the issue of impact has generally been addressed in a very partial and ad hoc manner (Goni et al., 2020). As a result, a comprehensive framework that encompasses all the dimensions of impact is lacking. In this research, we asked the following question: How can business model innovation combine economic performance and socio-environmental impact?

To answer this question, we conducted a research-action study (David et al., 2012), which followed three phases: (1) **an exploration phase** (Dumez, 2016), which explored the problems, (2) **an experimentation phase**, which proposed tools and a method to innovate the business model and take impact into account– and (3) **an assessment phase** to understand the implications for companies that use this methodology. To clarify the presentation of results, we propose to describe the different phases and methods in this order.

The first 'exploration' phase is based on 24 semi-structured interviews (Gavard-Perret et al., 2012) of large companies, start-ups, and investment funds – all positioned as having 'impact' as a core objective – and aims to investigate the relationship between business model innovation and the different forms of impact.

The first key finding is that while, in a comprehensive manner and as highlighted in the literature, impact has many different dimensions (i.e. economic, environmental, social and societal), impact-

driven companies and funders tend to have a partial view of impact and to be partial to some specific dimensions (e.g. companies targeting environmental impact tend to neglect the social impact of their decisions). Furthermore, even for such enlightened companies, their view of impact appears to The first key finding is that while, in a comprehensive manner and as highlighted in the literature, impact has many different dimensions (i.e. economic, environmental, social and societal), impact-driven companies and funders tend to have a partial view of impact and to be partial to some specific dimensions (e.g. companies targeting environmental impact tend to neglect the social impact of their decisions). Furthermore, even for such enlightened companies, their view of impact appears to be heavily influenced by a) regulations and policies and b) measurable impacts (e.g. tons of carbon, number of jobs created).

The second finding of this exploratory research is that an extensive change in business model is required to 'deliver impact'. Indeed, product/service innovation and market segmentation do not appear to do the trick. Instead, a business model innovation that includes impact management appears to mainly depend on the value creation and value capture components of the business model. Delivering impact is not so much about doing something different, but instead doing something very similar, but in a quite different manner, short of which even impact-driven companies may be accused of impact washing.

The third finding relates to the role of ecosystems. This research highlights that both internal and external stakeholders play a critical role in enabling companies to deliver impact. In this respect, ecosystem governance may well be the missing link between business model innovation and impact.

The last finding is related to the previous one, and it is the importance of governance bodies. They could have different names: 'stakeholders committee', 'impact committee', but they have the same goal: to initiate, develop, control and follow the integration of impact at the heart of the business model.

Results of phase 1 – Exploration

Result #1 - Partial and limited vision of the impact and business model.

Result #2 - Need to align business value model with impact by "unpacking" the different dimensions that make up the business model, but also by focusing on the way things are done rather than on proposing new impactful offerings.

Result #3 - Need to adopt an ecosystem approach to impact - mapping all the actors that gravitate around the business model and the company to understand how the business model can integrate and impact them.

Result #4 - Importance of internal and external governance in the integration of the notion of impact within the business model.

Figure 1. The results of phase 1: Exploration.

Following these different observations, we have proposed a methodology based on three tools to innovate the business model in order to deliver impact. This is the second 'experimentation' phase. To innovate the business model to include impact, companies must adopt a comprehensive definition and assessment of the concepts of impact, business model and ecosystem (see results of first phase). That is why we designed a methodology which allows an exhaustive approach of each concept and, at the same time, combines them. This method is based on three tools: a 360° Innovation Business Model (Rayna & Striukova, 2014b, 2014a, 2016) which is a pre-existing tool, an Impact Map and an Ecosystem Map.

This method has been tested as a managerial tool with three focus groups from three large companies (pharmaceutical, press and media, and energy provider).

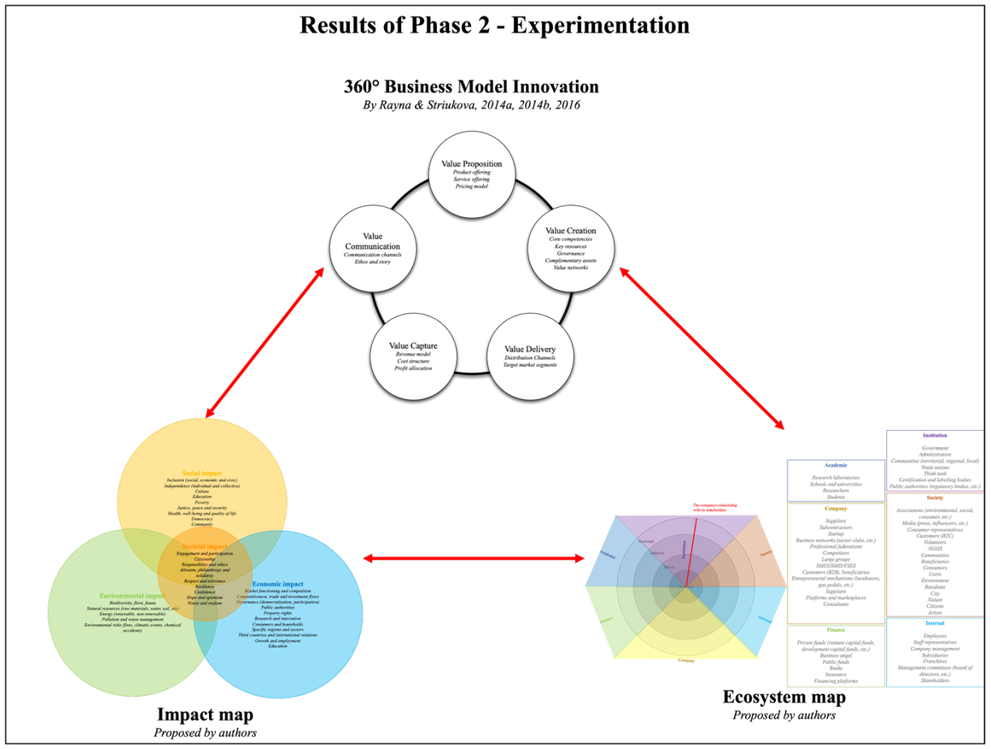

Figure 2. The results of phase 2: Experimentation. Innovation Business Model for Impact Method.

After testing the method with the focus groups, we interviewed different individuals to understand the implications for them and more broadly for companies of using this method; this is the **third 'assessment' phase.**

First, this method allowed the participants to broaden their perspective by taking into account other impacts. Generally, participants focused on one aspect - either environmental or social - of the impact. The use of this methodology allowed them to integrate new dimensions of impact into their thinking.

The second implication was to go beyond the proposal of a new offer. The 360° vision of the business model allowed them to question more strategic and internal dimensions of organisation. Furthermore, the question of the governance of these impacts emerged as an important issue for the participants.

Third, the method served to identify new stakeholders. Mapping of the ecosystem enabled the identification of new stakeholders who were initially excluded.

Finally, the concomitant use of the different tools served several purposes: diagnosis, ideation and formalisation. In all cases, the association of these different tools allowed us to create and define a method for integrating the notion of impact into the heart of the organisations' existing or non-existing business model.

Results of Phase 3 – Assessment

This method allowed us to:

Result #1 - Open up the reflection by taking into account all impacts.

Result #2 - Go beyond the proposal of a new offer.

Result #3 - Identify new stakeholders and involve stakeholders previously excluded.

Result #4 - Serve different purposes: diagnosis, ideation and formalization of innovation in business models for impact management.

Figure 3. The results of Phase 3 : Assessment.

This research examines how to innovate a business model to include impact. Through this research, we contribute to the theoretical literature on business model innovation for impact. Furthermore, this research offers several contributions for practitioners by proposing a concrete method.

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Climate Fiction@UCA (Cli FI @UCA)

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Anticipating climate change and imagining new trajectories: resources in Climate Fiction?

How to represent the effects of climate change? How to show the multiple possible refractions (social, economic, political, etc.) of such a phenomenon with planetary consequences? And above all, how can they be seen in a way that is perhaps more sensitive than scientific work such as that of the IPCC? There is indeed another way of anticipating: that of the imagination and science fiction. The latter has an advantage: the future is almost its favourite territory. And, precisely, an issue as massive as climate change strongly pushes us towards another relationship to time and in particular to the future.

For climate issues, as for other subjects, science fiction can be a heuristic tool and a support for reflection, as work in the humanities and social sciences has begun to show. Science fiction is a mode of representation, carrying stories, images, symbolic content, etc. But it can also be taken as a mode of problematization and a mode of exploration. It even has a relatively new branch that has developed in recent times. The expression "cli fi" (a contraction of "climate fiction") is increasingly used to designate (or even reinterpret) works that depict, to varying degrees, effects or issues relating to climate change.

Imaginaries obviously play an important role in the way in which communities apprehend the issues of their time. These fictions make it possible to both experience and experiment, that is, to feel and to put to the test. By definition, science fiction productions construct varieties of imaginable worlds by varying different ranges of parameters. What does it mean to live in a world with degraded, even almost untenable, ecological conditions? What does having to or not being able to adapt mean for individuals, communities, organizations, environments, etc.? These forms of thought experiments, elaborated in fictional frameworks, indeed show the conditions that human communities could encounter and they thus provide the setting to help perceive the efforts necessary for the latter to achieve a form of resilience. These are also hypotheses that are, in a way, tested in these fictional laboratories. One of the rare places where we can see "future generations" live, act and organize themselves (and for good reason) is science fiction and its imaginary constructions. It is a way of trying to describe how it would be possible to inhabit the worlds in preparation. And even, for certain stories, with a strong evocative power.

These fictions draw attention to the multiple dependencies in which humans find themselves (for everything related to living environments). In *Climate Fiction and Cultural Analysis. A New Perspective on Life in the Anthropocene* [1], Gregers Andersen argues for example that climate fiction should be seen as an essential complement to climate science, as it makes future modes of existence visible and conceivable in worlds not only deemed probable by science, but which are scientifically anticipated.

Notably, the dominant tone is hardly optimistic. Most often, the visions proposed are inclined towards a marked anxiety suggesting an apocalyptic horizon. Indeed, when it comes to its own planet, the human species as a whole seems to have come dangerously close to what should have been the limits, and the question now may even be whether the situation is close to a point of no return. Maybe to the point of fearing a condition like the "Condition Venus". This is the scientific hypothesis that serves as a terrifying and nightmarish spectre in the novel *Greenhouse Summer* by Norman Spinrad: it represents an irreversible outcome, risking plunging human communities into a world made difficult to live in by generalized warming. In the novel, the catastrophe has not yet taken place, but its anticipation becomes sufficiently convincing to come to sharpen conflicts between interests (economic and political in particular) which are all the more clearly revealed.

Thus, science fiction experiments with the conditions of living together. In the context of climate change, the relative comfort that has accompanied decades of economic growth is no longer guaranteed. Is this type of cultural production likely to feed "eco-anxiety" or to build ways to appease it? What will be left alive? Fiction can participate in an imaginary of general catastrophe and feed it. The important related issue, however, is how not to remain fatalistic. In fact, there seem to be more climate dystopias than optimistic fictions on the subject, which is hardly surprising as the change initiated seems inevitable. The variety of possible situations on a planetary scale is rendered more frequently among authors whose culture is not directly Western (see for example *Bangkok Wakes to Rain* by Pitchaya Sudbanthad).

Fiction is also a way of transcribing aspirations to change a state of the world, in this case by giving them shape in hypothetical futures, likely to maintain some hopes. Some stories allow us to explore other paths than those leading to complete collapse. This is what the American writer Kim Stanley Robinson tried to do, for example, through various novels. What social and political organization will it be necessary to find? How will this reorganization be able to absorb climatic drifts without producing new injustices? Will we need even more ambitious institutions than those that are currently trying to be put in place? The fictional framework makes it possible to include original institutions (compared to a present or past state) and to test their functioning: an international agency which could play the role of a «Ministry for the Future» for example, like the one imagined by Kim Stanley Robinson and whose mission would be to defend future generations and the forms of life present on the planet. Or, with the same objective, a carbon currency ("carbon coin") to have an alternative financing circuit in the fight against climate change. In this case, the novel is a way of expressing the author's concerns and exploring a range of imaginable options.

Is it possible to find solutions other than technoscientific ones (such as geo-engineering could be, as the ultimate solution)? How is it possible to imagine a world without cars for example, or at least one in which their place is significantly reduced? Solarpunk fictions, in the process of becoming a subgenre in their own right, try to show societies operating on different principles, first in the technologies and energy resources used, but also in their guiding values, which are more egalitarian (including in relationships with other species), more cooperative and less profit-oriented.
Can these fictions encourage reflection on all these issues, or even elicit certain forms of reaction or commitment? We can hypothesize that this kind of fiction is also useful for collectively building an ethics of the future. It will be interesting to follow the role they take on in a world whose climatic conditions, and even ecological conditions more broadly, are likely to change significantly. The mass of future uncertainties raises many questions, and it is also these that science fiction metaphorizes through its stories. As Carl Death says: "Climate change is altering how the future is imagined." Could future fictions be anything other than climatic fictions?

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Designing the SKA Observatory's supercomputers: maximising science while minimising their environmental impact

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In observational astronomy, angular resolution is determined by the receiver's diameter and instrument sensitivity is driven by its collecting area. The pursuit of ever fainter and colder targets often representing farther and older objects is currently driving the trend towards bigger optical and radio telescopes. Modern radio-astronomy relies on arrays of antennas to increase resolution and produces images via aperture synthesis, a technique derived from interferometry which, in the radio domain, is carried out through data processing. The SKA is an international project to develop the world's largest radio observatory (SKAO) with the completion of phase 1 expected by 2029. With its two telescopes located in Australia (SKA-LOW) and South Africa (SKA-MID), the SKA will address an impressive variety of fundamental physics and astronomy topics.
Data-wise, the SKA represents a major leap forward. Radio-waves are digitised at the level of the 197 dishes (SKA-MID) and 131 072 antennas (SKA-LOW) and the data are transported to two edge computers, the Central Signal Processors (CSPs), where preliminary operations are performed to reduce the data flow. As a result, 1 TB/s of data is then transferred to two supercomputers, the Science Data Processors (SDPs), where it is transformed into science-ready products and volume reduced to 700 PB/year. The data is finally distributed to a network of computing centres, the SKA Regional Centers Network (SRCNet), where it is stored and made accessible to scientists for interpretation.
The SDP is at the frontier between the highly predictable, simple and repetitive processing of the CSPs, which calls for dedicated hardware, and the versatile use of the SRCNet by the scientists, which points to data centres, while facing both important data flows and a need for running a diverse set of tasks. The estimated 125 petaflops of peak processing power required from each SDP [1] compares with the performance of the Sierra supercomputer which currently ranks 6th in the TOP500 [2].
Supercomputers consist of a set of nodes[1] integrated in blades and arranged in racks which are themselves interconnected with fast networks. Systems with 1.5 million processing cores like Sierra include 4320 nodes and 240 racks [3] which amounts to a tremendous amount of high-technology components organised in a large and complex system. Evaluating the environmental impact of such systems is complex as it requires considering the full life cycle (manufacturing, transport, operation,

[1] individual computing unit

disposal) which involves many economic operators. It is also complex due to the multiplicity of aspects to be considered, like use of natural resources[2], energy[3] and pollution[4]. Although significant progress has been made over the last decade to improve the energy efficiency of systems, the power consumption of data centres is still growing due to bigger systems and the greater number of data centres (rebound effect).

SKAO has acknowledged the complexity of procuring two such machines in what is not a high-performance computing project. A complexity related to capital and operational costs, fast-evolving technologies and the difficulty of accurately specifying the need. The SDPs are hence considered part of the telescopes because they need to be available both to process the data and to provide feedback to the antennas and CSP within seconds for observations to be possible. This is an innovative approach to data reduction compared to the classical offline approach.

While the objective of the SKA is to further our understanding of the universe and fundamental physics with positive societal impacts, notably in terms knowledge and innovation, the environmental impact of the SDP, which is only part of the SKA, is significant. With installations in South Africa and Australia, where the energy mix emits considerable greenhouse gas, it was roughly estimated that the construction footprint for the SKA would be 312 kt CO2e and the annual operations footprint 18 kt CO2e / year [5], with a significant share owed to computing infrastructures.

SKAO has included sustainability as one of the core values of the observatory. Together with budget, this has led SKAO to devise a power plan to reduce its exposure to fluctuations in the price of energy and reduce greenhouse gas emissions (e.g., with solar plants close to the SDPs) and to set an upper bound to the power consumption of the SDP at 2 MW [6]. This is a very aggressive objective in the light of the current efficiency of High Performance Computing (HPC) systems based on uncertain extrapolation of current trends in power reduction to the date of the systems' procurement.

The cost cap for the SDPs in SKAO's budget follows a similar strategy and is also very aggressive. Hence SKAO has identified a risk that, for the allocated money and power, the procured SDPs might limit the exploitation of the telescopes [7]. Procuring the SDPs will be led by France and will build on a co-design activity to achieve an optimised design with matching software and hardware for maximum efficiency. The Observatoire de la Côte d'Azur leads this effort and, while the details of the scope are still being discussed with SKAO, it is our understanding that its objective is to allow the SDPs to achieve maximum science return within the assigned envelopes while minimising their environmental impact.

The community developing embedded systems has a long history of co-design as a result of targeted applications and highly constrained conditions for operation (power, volume, mass). Until recently, HPC has relied mostly on scaling[5] existing systems: Dennard's scaling and adding racks provided regular increases in performance. Its recent demise has led the larger systems to consume increasing amounts of power so that, by 2014, IBM made a case for increasing performance with a heterogeneous architecture mixing GPUs and CPUs during the development of Summit and Sierra, based on predefined use cases [8]. More recently, a system's analysis of power consumption was carried out for Fugaku to improve its efficiency, also for predefined use cases [9]. Co-design, as a means to jointly specialise the hardware and software architectures of a machine for more targeted uses, while still using commodity components, is now the agreed way to increase performance [8] [9][10] but is only an emerging practice in HPC.

Such a strategy is well adapted to the SDPs which, although they will need to run diverse tasks related to different observation modes and be able to evolve as the science progresses, are intrinsically specialised in the sense that they are part of the telescopes. The ongoing development of the corresponding software, while it makes describing the expected use more difficult, also offers additional opportunities in deeply revisiting the software architecture at the application level and also for the supporting stack.

CNRS INSU has adopted a twofold approach to this challenge. First, with engineering activities carried out as an international collaboration led by Côte d'Azur Observatory and ASTRON and inscribed, like the SCOOP team, in the SKA project itself. Then, with upstream research and R&D soon to be organised under the umbrella of a common laboratory (ECLAT) – between CNRS, Inria and Atos and directed by the Paris Observatory – intended to feed SCOOP activities in the longer run.

Besides benchmarking the software to estimate the performance achieved and understand what limits it, SCOOP also tests behaviour on a variety of hardware and simulates execution via models of the SDP in order to explore the solution space and identify promising avenues. Beyond this effort to improve the match, SCOOP also intends to contribute to a system-level view of the SDP in order to refine the architectural and operational needs and contribute to devising a system able to adapt to scarce temporal, computational and energetic resources. Developing a long-term vision of the management of the SDP is also proposed, including staged deployment, maintenance, extension and decommissioning to reduce the capital environmental cost of the SDP over its entire life cycle. In addition to enlarging SCOOP's horizon with a prospective view fuelled by upstream research efforts or making recent findings applicable, ECLAT will provide expertise on the design of supercomputers through the contribution of Atos. The hope is that this joint and long-running collaboration will lead to a shared understanding of needs and solutions and result in a finely-tuned, tailored system when the time for procurement comes.

The design and procurement of the SDPs is a challenge in terms of complexity, cost and schedule, especially if SKAO is to fully profit from the investment of building the antenna arrays – in comparison with the LOFAR, NeNuFAR, MWA and pathfinder radio-telescopes whose current use is severely limited by the associated computing resources. The environmental impact adds to this challenge while not being entirely disconnected from budgetary constraints. The co-design endeavour led by France in the frame of such a large project triggers interest in HPC research communities and is expected to foster research and innovation at the hardware and software levels but also concerning the process of developing and operating such infrastructures. Besides the SDPs, the tools and know-how developed could apply to the CSPs and SRCs within the SKA and, beyond, to HPC infrastructures associated with research experiments, in the search for an improved balance between science's high-end requirements and environmental sustainability.

[2] 180 kg of raw material to produce a smartphone

[3] 12 MW to operate Sierra

[4] Mean time between failures is of the order of minutes for data centres [4]

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4 QUALITY EDUCATION

Ecological transition : a call to develop a structured network within Université Côte d'Azur for exchanges on education and research

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In education : institutional commitment and current initiatives

Université Côte d'Azur is about to sign the Grenoble agreement [1], which makes it mandatory, de facto, not only to raise awareness but also to educate 100% of its students on the challenges of ecological transition.

Beyond this agreement, which demonstrates the institutional commitment of our university, efforts in this area have already been undertaken in many of its education departments to offer courses at the Bachelor and Master levels. By way of illustration, the signatories of this agreement are involved in teaching the following courses :

- Challenges of the energy transition: a 15-hour course offered to all first-year engineering students at the Polytech Nice Sophia engineering school.
- Digital and environment: a 24-hour minor offered in all Master's degrees associated with the Digital Systems for Humans Graduate School.
- Chemistry and atmospheric pollution: a 15-hour course/lab offered as an elective to first-year students in Science and Technology bachelor's degree programmes.
- Environmental problems, a 9-hour course included in the «Issues of contemporary society 2» course for first-year bachelor students in Social and Human Sciences.

The first item is an example of a generic course that presents the basic elements of the debate. The second is an example of a specialised master's course that focuses on the environmental impact of the information and communication sector and possible solutions it can offer. The third aims to raise students' awareness of environmental chemistry by addressing the phenomena of air pollution (destruction of the ozone layer and climate change). The fourth proposes an introduction to a social science perspective on these issues by exploring the mechanisms behind public issues with the aim of both understanding current institutional responses and their limitations, and seeking ways of change.

Discussions are underway to create courses within some Bachelor of Technologies (IUT) and Mater in informatics and management (MIAGE) education programs. Colleagues are intensively collaborating in an attempt to share, exchange and support each other in this pedagogical effort.

Many similar initiatives are undoubtedly underway in other education departments of the university.

The following insights can be drawn from our personal experience :

- The problem to be addressed is inherently systemic: it affects the entire society, and therefore requires a multidisciplinary approach, particularly at the undergraduate level. Greater specialisation can occur in graduate programmes. Research and teaching within Université Côte d'Azur and more generally in French higher education is organised to operate in silos, which complicates this collaboration. Beyond this organisation, questions arise about the neutrality of faculty members on the knowledge taught. The manifesto by the CNRS Labos1point5 think tank «Dare to teach the ecological transition» provides an overview of these questions [2]. Collaboration between colleagues in the hard sciences and the broader humanities is crucial to addressing these issues.
- Because of its multidisciplinary dimension, especially its human and societal dimension, the topic to be taught, whether it is climate change or the ecological transition, goes beyond the usual framework of university education. The purpose in this case is not only to teach what may become profession or a line of research in the future, but what may become the environment in which our students, as future citizens, will live. The approach is no longer to provide competencies, as was strongly encouraged in recent years, but to provide an intellectual education to help citizens make decisions in an uncertain context. As faculty members, this implies the need for us to re-examine our responsibility in pointing the way to a generation of students. The task is ambitious, but it is crucial, even if it remains confusing because it breaks with the ordinary, for both teachers and students.
- We have often observed a feeling akin to anger among the young generation faced with what it considers to be betrayal by the adult world. The recent article by Julia Steinberger, author of the IPCC, who is very involved in communicating with the general public, addressed to young people revolted by the political inaction of adults is emblematic of the problem [3]. The subject to be taught therefore has an ethical dimension, which must be addressed by joint, transdisciplinary collaboration that should allow us to redefine the epistemic and ontological disciplinary frameworks in the light of the challenge imposed on our society and on faculty members alike.

These preliminary and partial ideas collected in the urgency of the moment and of the crisis that is unfolding confirm the need to develop a forum for sharing and discussing within Université Côte d'Azur. This initiative must start within our university's current structures, but it requires changes of a completely different dimension both within Université Côte d'Azur and French higher education. This new challenge cannot be added to the current assignments of faculty members, as the task is too important and time-consuming.

It is also essential to join in national initiatives, such as the recent report published on March 29, 2021 "Teaching ecological transition in higher education" by the committee chaired by Jean Jouzel [4], which advocates a 6 ECTS course of for all bachelor students, or the manifesto "Training engineers of the 21st century" [6], drafted jointly by the Shift Project and the INSA Group.

The Lyon engineering school (INSA), which is far ahead on these subjects, has developed specific courses in its preparatory cycle, as well as specialised courses that apply to each engineering field. This institution is prepared to deploy more than 30 lecturers at the beginning of the next school year, who have trained each other and are ready to face the students. The transition to a scale such as that of Université Côte d'Azur is a real challenge, which requires means of collaboration that will allow specific solutions to emerge.

In education : recommendations

In the light of these considerations, we recommend to set up, from September 2023, a teaching for all undergraduate students. This teaching should :

- Be based on content developed from multidisciplinary research.
- The course format should encourage the participation of lecturers from civil society, for example, and not be limited to lectures by experts who are bound by the constraints of their discipline.
- The teaching should absolutely be in-person, in small groups, using participative pedagogical methods. To be worthwhile and achieve results, students must be involved and have a stake in the process. Graduate students (master's or PhD students via specific financing for tutoring) should also be involved.
- Previous experiences and feedback from colleagues in other institutions have confirmed that the human and relational aspect is essential. The program should not therefore be exclusively based on MOOCs.

- Be taught by faculty explicitly mandated by the institution, who do not consider this task a sacrifice (i.e. who do not teach these courses at the expense of more highly valued tasks).
- Be coordinated full-time by faculty members closely collaborating with the eco-responsible task force of Université Côte d'Azur.

In short, the institution must clearly and massively invest, in terms of communication but also financially, in providing these courses.

In research: transition in the laboratories

The transition challenge also has an impact on research within Université Côte d'Azur. Many laboratories are engaged in a process of measuring their ecological footprint using the GHG emission assessment tool developed by CNRS Labos1point5.

As of June 15, 2022, more than 450 laboratories in France have conducted more than 750 GHG inventories that have served as research material for the CNRS think tank in addition to helping the laboratories themselves. While an annual GHG emission inventory is a first step, many laboratories are relying on these assessments to develop a five- or ten-year ecological transition strategy to reduce their GHG emission. Labos1point5 is currently working with pilot laboratories in France and is preparing to publish, in autumn 2022, kits to help laboratories with their transition process. Once again, this issue should involve much more than the mere implementation of technical recommendations (as is also the case with education). It requires an exercise in participatory democracy within laboratories. These efforts, which have an impact on the very core of laboratory life, must be coordinated with teaching and must contribute to greater interdisciplinary exchanges at least for the purpose of consistency: how can one teach about the energy transition without being, within one's own domain, engaged in such an approach?

In research : recommendations

As in the case of developing courses dealing with the climate crisis and the ecological transition, preparing laboratories for the transition calls for creating forums of exchange between the laboratories of Université Côte d'Azur and beyond, in the local context. These physical and intellectual spaces could be a forum for exchanges on the changes required in our research itself with regard to the transition. When considering research as a knowledge project, the best way to address this systemic problem is a systemic approach in which each discipline can contribute.

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Education for sustainable development and change of social representations

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Throughout the 20th century, scientific research has greatly contributed to the emergence of an ecological awareness on the part of public authorities as well as the civilian population. The word «ecology» comes from the Greek terms «oikos», habitat, and «logos», discourse, and corresponds to the study of the interactions between the living organisms of an ecosystem (Haenckel, 1866). Research has thus made it possible to put words to these interactions in order to better understand them. However, the ecological crises of the twentieth century are generating a growing concern in Western society, which is starting, since the Second World War, to think about new ways of living. The «era of transition» is here, with the objective of finding a new socio-economic model, through new ways of consuming, producing, working and living together. In addition to ecological concerns, civil society is beginning to doubt the validity of the policies implemented by public institutions, which is leading to the emergence of new citizen movements that seek to mobilise public opinion around causes of global interest, to propose new social representations that are more ecological and to make themselves heard by the institutional world. This period of Transition, in which we have been living since the 1960s, has seen the development of numerous experiments throughout the world. In parallel to the civil population, political institutions are also becoming aware of the need to work towards a new, more ecological, world order. After the Second World War, the Earth Summits, organized every ten years since 1972 by UNESCO, contributed to the implementation of global policies for sustainable development, officially defined as «development that meets the needs of the present without compromising the ability of future generations to meet their own needs». The «2030 Agenda for Sustainable Development», signed in 2015, following on from negotiations that began at the 2012 Earth Summit, is based in particular on proposals from civil society, the financial community and various other socio-economic actors. This situation highlights the fact that a cultural change is underway, since the end of the Second World War, which aims to move the currently destructive Western culture towards a kind of culture of life. How are these new ideas and practices, as well as their corollary representations, transmitted ? What consequences does this evolution have for social cooperation ?

Following on from the first Earth Summit, the Belgrade Charter, signed in 1975, provides a «world framework for environmental education». It advocates «a new universal ethic that recognizes and feels strongly the complex and ever-changing relationship between human beings and their fellow human beings and nature», an equitable distribution of environmental resources and the establishment of a system of environmental education to achieve the first two recommendations. This environmental education must concretely allow young people as well as adults to become aware, responsible and supportive of their natural environment, through the learning of new knowledge and representations. However, it was questioned in 2004, because it was considered too diffuse and insufficient, concerning didactics and pedagogy. Education for the Environment and Sustainable Development replaces it, with the objective of generalizing and harmonizing the programs, while making them transversal and interdisciplinary.

In 2007, new recommendations from scientific researchers led to the implementation of Education for Sustainable Development (ESD), which notably advocates the training of teachers involved in this education, as well as an attitude of responsibility towards the living, human and non-human world. This evolution is important because it is now a question of considering local as well as global spatial relationships, time scales that are situated between long term and sustainability, as well as the transmission of new citizen values specific to the protection of biodiversity.

However, this base of knowledge, now inserted in school programs and in the daily behaviours to be adopted by the population, is conveyed through the global, national and individual representations of its transmitters - political bodies, the education system and teachers. The transmission of any knowledge whatsoever cannot, in fact, be done without the representation that each person initially has of it, on the part of both the teacher and the learner. Thus, in France, teaching is very theoretical and generalized, unlike in Germany, which takes into account regional cultural particularities and the practical application of knowledge. The representations may differ according to the economic, social and environmental reality of the countries, but also according to the culture of the teachers. However, the paradigm shift implied by a culture of sustainable development requires, as a corollary, a change in representations. «Education for sustainable development must constitute a philosophy of life likely to lead everyone to make reasonable and non-rational choices as explained by economic theory» (Diemer, 2013) and yet, the political choices of biodiversity management remain very anthropocentric, which results in privileging the life of species considered beneficial for human well-being at the expense of other living species (Maris, 2014; Maris & Reverêt, 2010). These representations of Life are not in line with the values defended by the Earth Charter, signed in 2003 by members of UNESCO and IUCN, as well as many other personalities, international organisations and individuals from around the world. The Earth Charter states, among other things, that «Our environmental, economic, political, social and spiritual issues are interdependent and together we can find integrated solutions. To realize these aspirations, we must choose to integrate into our lifestyles the principle of universal responsibility, referring to the Earth community as much as to our local communities. We are citizens of both different nations and one world, where the local and the global are intertwined. We all share responsibility for the present and future well- being of the human family and all other life forms. The spirit of solidarity and fraternity towards all forms of life is strengthened by respect for the mystery of creation, by recognition of the gift of life and by humility before our place as human beings in the universe. These inconsistencies, in the representations conveyed about Life, are found in the texts of laws, since if more and more governments grant animals the status of living

beings, this is not at all the case for plant species, which are always relegated to the rank of things. Yet, gratitude, humility and empathy towards one's fellow beings, human as well as non-human, must be the priority values to be transmitted in the framework of education for sustainable development.

Faced with these challenges, a didactic as well as a pedagogical adaptation is necessary in order to transmit representations of sustainable development and of the Living World that are in phase with the contents of Education for sustainable development and change of theoretical representations.

The search for more ecology and sustainable development, since the 1960s, has allowed the multiplication of experiments in this sense, forming the premises of a complex education. Thus, more and more educational institutions are putting theoretical knowledge into practice through workshops and educational gardens. The latter allow for the contextualisation and acquisition of know-how that can go beyond mere technical expertise with conscious learning. Developing workshops and experimentation spaces in schools, whatever their level of education, can allow learners to become aware of their gestures, behaviours and thoughts when faced with daily or new acts, which are often performed in an automatic, procedural, or even irresponsible manner. Thus, more and more organisations are setting up circular systems in their internal organisation, such as the installation of vegetable gardens following permaculture methods, which will be used in part for canteens, composters, or fairs to give or exchange objects rather than throwing them away.

Moreover, educational vegetable gardens open the senses and empathy, towards humans as well as other living species, in a totally ecological context. They can also help develop techniques of letting go, adaptation and resilience.

The field of recycling also holds a very important place in the installation of a more ecological and sustainable daily life. However, there is still education to be done on this subject. It is necessary that the institutions propose sorting garbage cans in each office and each public place to constitute a reference, an example, in the eyes of the public and the employees. This also implies a rigourous approach in the choice of public markets and in the contribution of each individual.

Gradually, it seems that citizen movements and institutions are converging towards the same objective, or even joining forces to contribute to the development of these philosophies of life through practical teaching, in schools, during open houses of public and private spaces, or through the organisation of festivals. The learning of daily eco-gestures is thus facilitated by a growing cooperation. This evolution shows, moreover, the importance of the concepts of complexity and circularity, which are expressed through the links between the actions and eco-gestures of this daily life.

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Impact of Pollution on Health

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Introduction

The practice of regular and consistent physical activity has long been recognised as an essential factor for good health and aging well [1]. Sportswomen and sportsmen are often considered in our society as a model of good health. For example, Olympic athletes and Tour de France cyclists have a longer life expectancy than the general population [2,3]. However, practicing a physical activity or a sport in unfavourable environmental conditions may not be without danger, even in apparently healthy people [4–6]. For example, many incidents and discomforts occurred during the 2019 athletics championships in Qatar, and isolated health concerns regularly occur during local sporting events, especially when the temperature is hot. During the 2021 Tokyo Olympics, medical teams were prepared and were able to take care of athletes whose core temperatures had sometimes risen to 42°C, potentially fatal for a non-trained person. Scientific research has accelerated in recent years on the effects of heat on the human body of elite athletes, the role and methods of acclimatization to avoid heat stroke (https://pubmed.ncbi.nlm.nih.gov/?term=athletes+heat). The place, dates and times of competitions may be affected by the weather in the future, as was already the case of the Tokyo marathon during the Olympic Games 2021 which was moved to the North of Japan to avoid the too intense heat.

Global warming, due to its obvious risks and effects on the health of the athletes, often masks the effects of atmospheric pollutants to the population, and yet it will be accompanied inexorably by a degradation of the quality of the air [7–10]. Air pollutants, with a few exceptions, are often odourless and colourless and unless they have an external indication (governmental association or individual sensor or World Health Organization, etc.) of their concentration in the atmosphere, few people know that they are exposed to them. However, they have a significant impact on health, causing premature deaths and an increase in emergency room admissions with each pollution episode and with years of exposure [11,12]. Megafires, for example, have been heralded as the future, with the accompanying considerable degradation of air quality, potentially deadly [13,14]. In 2019, Wildfires occurred in Australia during the Australian Open Tennis Tournament, and many players were unable to play due to coughs, nausea, and other various symptoms (https://www.bbc.com/news/world-australia-50497492). Some countries have dramatic concentrations of air pollutants, and sporting events continue to be organised, despite a lack of data on the future consequences on health (https://edition.cnn.com/2019/10/18/asia/delhi-marathon-pollution-intl-hnk-scli/index.html). In 2019, the Iron man in Nice (France), for example, occurred during a heat wave accompanied by an

ozone pollution alert. Without resources to know what to do, the organisers reduced the distances randomly without scientific rational to avoid a cancellation (https://france3-regions.francetvinfo.fr/provence-alpes-cote-d-azur/alpes-maritimes/nice/canicule-parcours-ironman-france-nice-2019-raccourcis-1692562.html). Only during the Olympic Games, since at least those of Los Angeles in 1984, are preventative measures taken to reduce local production of pollutants during the event [15], such as reduced traffic [16], but this is not the case for athletes in other events or during the year and we cannot act on the acute pollution linked to natural events like mega fires, or volcanoes. The population of sportsmen and women, who represent a model of health, is too little studied, but is nevertheless a privileged target, because (1) they represent the model of good health in our societies, (2) they have capacities of adaptation and acclimatization often out of the ordinary and sometimes absent or failing in sick or sedentary people, (3) if the practice of a sport in a polluted environment becomes deleterious on their health, this would have dramatic consequences for the future of humanity, which would have the choice between becoming ill while practicing intense sport in an overly polluted environment or not doing so and being exposed to all the chronic diseases linked to sedentary life and pollution. Thus, some current epidemiological data indicate that the health benefits of physical activity (active transport in general) remain greater than the harms of air pollution [17], for example in European societies for healthy subjects. However, in countries where pollution is significant, there are no further benefice of exercise (at a mean ventilation of 63 l/min corresponding to 65% of maximum oxygen uptake) after 15 min (tipping point) and the air pollution health risks surpassed the exercise benefits after 75 min (break-even point) [6]. It should be noted that these studies are far from taking into account the duration and the intensity of the efforts of the sportsmen/women, in particular of endurance, and that often concerns particulate matter (PM) only. Children may also be more at risk of air pollution exposure even at levels slightly below air quality standards [18] and in polluted cities, especially with high level of ambient ozone [19], the most active children have an increased risk of developing respiratory problems, such as asthma compared to less active ones [20].

Air pollution is a generic term, but the chemical compositions and types of pollutants are extremely varied, and it seems that the mechanisms of action of each are different. While some are irritants to the airways, others may be carcinogenic. Air pollutants may be gas (Ozone (O3), nitric oxide (NO), sulfur oxide (SOx), carbon monoxide (CO)) or particulate matter. They may be of primary source, from human or natural origin, or secondary, formed by a photochemical reaction, such as O3 formed through the reaction of sunlight, NO, especially dioxide (NO2) and volatile organic compounds [21]. Particulate matter is a very large category of molecules characterized by the size of the PM, their composition, mass, shape and electrical charge. Generally, they are characterized by their size, PM10 and PM2.5, being generally measured in the atmospheres of the cities worldwide, and with PM1 and ultra-fine particles (PM0.1) being the most studied in health studies. As the inhaled dose, whatever the pollutant, depends on its concentration, the ventilation of the subject, and the duration of exposure, people exercising are particularly exposed to the deleterious effect of pollutants. Indeed, sport and physical activity, through an increase in the person's breathing, may increase the risk of penetration of pollutants in the airways, lungs, blood, and organs [22,23]. The ventilation a rest is around 6 l/min, it may increase to around 50 l/min in healthy people exercising at light to moderate intensity and 100 l/min in young physically active people at high intensities, but may be sustained for a few hours well above 100 l/min and more than 200 l/min over a few minutes in young elite endurance athletes. There is an insufficient number of studies that can allow us to conclude on the short- or long-term risks of exposure to different pollutants in athletes of different sports, the regulations to be adopted, to identify healthy people at risk, and also the management and prevention plans to be adopted (nutrition, medication…) [23–25]. The international sports federations have tried to regulate, for many years, the conduct of competitions in cold or hot temperatures, taking into account the WBGT [26–28] (https://www.ccsam.ca/competitive-skiing/event-information/event-cancellation-policy-2/) . In case of a health threat, they have the possibility to cancel or postpone competitions, and these policies are currently well applied. In case of high pollution level, there is no rule at all, and we don't know what to do.

Several scientific publications have very recently underlined the lack of studies on the effects of the different pollutants on the respiratory health of healthy people performing an exercise. Only ozone has been studied, especially by Californian teams in the 80s, and shows an obvious impact on pulmonary function and respiratory difficulties. In view of the Los Angeles Olympic Games in 1984, research was carried out, in particular because of the recurrent high ozone concentrations in this region [29,30]. Ozone is the pollutant that usually accompanies heat waves and is of particular concern for the future. Worryingly, it may be locally more difficult to reduce ozone concentrations than those of PM for example (by reducing traffic for example). After the COVID-19 lockdown period, PM and NO2 emissions (mainly related to reduced traffic), were drastically reduced in Europe and China [31]. On the other hand, ozone increased in the same cities studied [31]. In healthy non asthmatic non allergic adults, it may provoke severe falls in lung volumes, sometimes around 50% during light to moderate exercise, and even more in asthmatics [23–25,32]. As a consequence, rare studies showed that up to 40% of a group of healthy well-trained athletes may stop exercise when performed in the presence of ozone concentrations similar to episodes of pollution observed in Europe, due to a severe respiratory discomfort [32–34]. Some rare studies of concern suggest that regular inhaled corticosteroid treatments may have no effect on airway response to ozone [35–37], and may even worsen symptoms and fall in lung function when exposed to ozone in people with respiratory pathologies[38,39]. This is of particular concern because inhaled corticosteroid therapy is the preferred treatment for inflammation in many lung or airway diseases (asthma, chronic obstructive pulmonary disease), but also for athletes having exercise-induced bronchoconstriction ("exercise induced asthma") [40]. It is now well-known that endurance sport may favor the development of such diseases due to the high-level of ventilation but also inhalation of pollutants [41]. In a disturbing way too, only a few studies exist but report the complete inefficiency of inhaled Beta2-agonist (Salbutamol, albuterol) to reverse the fall in lung function due to ozone when exercising in elite non-asthmatic cyclists [42,43]. This medication is the rescue medication or taken as a preventive measure by many asthmatics, whether or not they are athletes, and particularly before exercise to avoid an attack of exercise-induced asthma. The mechanisms of the fall in lung function due to ozone and of asthma crisis may be different and it may explain why inhaled medication is less effective during ozone peaks and why asthmatics lose control of their disease, leading to emergency room visits and death for some.

LAMHESS's (Université Côte d'Azur, France) associate colleagues, who work for the World Athletics Medical Commission, have continuously measured pollution in athletics stadiums around the world since 2019 and aim to see the effects on the health and performance of athletes, but also to plan

the schedules and dates of sports events accordingly. Our laboratory (LAMHESS) is also represented regularly in international working groups on sport, health and pollution, including the International Olympic Committee (IOC) medical commission. LAMHESS aspires to bring together researchers from around the world working on pollution, health and performance to accelerate the production of knowledge in regular athletes, elite or not. This network is nascent but will allow the standardization of studies between countries because the multidisciplinary nature of studies requires toxicologists, atmospheric chemists, epidemiologists, sports science specialists, physiologists, specialized doctors, nutritionists, international sports federations, etc. Our studies will relate on the one hand to field measurements, with measurement of the pollutants and physiological variables in situations of exercise by practitioners, and on the other hand will relate to exposure in inhalation chambers to better understand the mechanisms of each pollutant. We will look at a wide range of parameters such as the mechanisms of action of various pollutants, including various types (gas, particulate, etc.), and composition, why some subjects are sensitive and others not, what is the recommendation threshold for air pollutants according to their properties for postponing or cancelling a mass or elite sporting event, what are the management and prevention plans, etc. The risk of not accelerating the pace of these studies is to find ourselves without a solution to save people sensitive to pollutants (the current medication being insufficient for some pollutants) and to see an increase in the number of deaths or respiratory or other diseases among athletes during events, training or in recreation courses. For now, when an acute air pollution episode is announced in Europe (in general level 2 or 3), sensitive people (adults and children) with asthma or chronic disorders are currently told not to do physical activity in order to avoid emergencies and death. With the air pollution accompanying global warming, it is likely to affect more and more people and finally what will we do? Force everyone to stop doing sports, knowing the harmful impact of physical inactivity ?

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OTECCA, a territorial observatory to foster citizen science on socio-ecological transition

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The release of the Working Group III contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change in April 2022, dealing with the mitigation of climate change, highlights a recent strand of the academic literature dealing with "the growing role of non-state and sub- national actors including cities, businesses, Indigenous Peoples, citizens including local communities and youth, transnational initiatives, and public-private entities in the global effort to address climate change" (IPCC 2022). For the keen observer of the climate change issue, this literature is reminiscent of a prescient article by Elinor Ostrom written in 2009 for the World Bank, in which the author argued that single policies adopted only at national and international scales are unlikely to cope with climate change. For the author, "a polycentric approach at various levels with active oversight of local, regional, and national stakeholders" is necessary. This approach would encourage effort at multiple levels and develop methods adapted to local realities and would therefore form an indispensable complement to national and international policy initiatives. The interaction of different stakeholders at different decision-making levels (e.g., from local to national) would build the necessary trust to forge a collective response to climate change.

The scientific community must be a stakeholder in this interaction. It is a question not only of society's trust in its researchers, but also of the need for scientists to answer society's questions on the complex issue of how to deal with climate change, of necessary behavioural changes, etc. However, science with society is not a highly developed practice. It can only fully emerge if it is institutionally accompanied. Various institutional forms have thus been developed: science shops, collaborative observatories, etc. These frameworks allow representatives of society such as associations or local authorities to exchange with scientists, co-construct research projects, or be involved in data collection. Since the issues raised are interdisciplinary in essence, these institutional forms must be capable not only of organising the interaction between science and society, but also the collaboration between different disciplines in this interaction.

In this framework, the idea of implementing such an institutional structure in the Alpes-Maritimes area emerged in 2018 during an event co-organised by Université Côte d'Azur (Maison des Sciences de l'Homme et de la Société Sud-Est, MSHS Sud-Est) and the association Synergie de la Transition 06 (named "Assises de la Transition Écologique et Citoyenne Alpes-Maritimes et Alpes du Sud", autumn 2018). In 2020, Université Côte d'Azur set up the structure within the Maison des Sciences de l'Homme et de la Société Sud-Est, with the creation of the Observatoire de la Transition Écologique et Citoyenne Côte d'Azur (OTECCA), observatory for socio-ecological transition on the Côte d'Azur, composed of researchers, association representatives and student organisation representatives.

OTECCA aims to interface with scientific as well as civil communities in order to gather, produce and share knowledge of socio-ecological transition in the Alpes-Maritimes territory and to increase citizens, decision makers and other stakeholders' actions through better collaboration. It addresses a wide range of themes stretching from agriculture, consumption, and culture, to energy, economy, education, environment, food, health, housing, solidarity, transports, etc.

OTECCA pursues three missions:

Document and analyse the territory from the angle of ecological and civic transition

OTECCA gathers, organises and produces multi-sector data on socio-ecological transition available to researchers and the general public. The goal is to provide information on the current state of play in the Alpes-Maritimes territory for analyses of vulnerabilities, potential, and future developments.

Implement and promote collaborative science-society research

OTECCA strives to connect scientists and researchers with civil society stakeholders in order to implement projects built hand-in-hand on the territory. While research needs on environmental as well as civic transition can emerge from both researchers and civil society stakeholders, OTECCA finds the right partners and brings into existence a collaboration between stakeholders in order to build and carry out a research-based project. The social utility of research is thus strengthened. The collaboration also contributes to scientific innovation with new research questions emerging from society's day-to-day realities.

Foster and spread scientific culture as well as citizen science

OTECCA strives to foster interactions between scientific and civil communities in order to develop knowledge sharing as well as good practices in analyses and actions. To do so, OTECCA positions itself as a means for scientific mediation through a variety of actions such as collaborative projects, conferences, seminars, training, or workshops.

Since its creation, OTECCA has facilitated several projects. As an example, in November 2020 OTECCA initiated a research project built hand-in-hand with "Les Petits Loups Maraîchers" (PLM) association in order to question the suitability, relevance and future of the association model from agricultural, energetic, economic, social and political perspectives. PLM is based in Bar-sur-Loup (Alpes-Maritimes area) and it develops a collective approach to produce organic local food on three different plots. The multidisciplinary approach needed for the questions that emerged

specifically engaged OTECCA in the research project. The research has led to several student group projects and internships within Université Côte d'Azur (UCA) and its related partners, in energy and technology, political science and psychology. As an example, in a six-month internship, a student in social psychology worked on understanding the values of the PLM association members and factors impacting on their commitment to the organisation and on the adoption of eco-responsible behaviour. Not only did the study allow the association to better adapt to the needs and motivations of its members, it also brought to light unexpected and interesting results in terms of behavioural psychology.

The Scientific Advisory Board of OTECCA truly considers that a reflection on science with society to foster initiatives in socio-ecological transition can be undertaken during climate conferences and other international meetings. There are at least two ways of doing so.

The first one considers how to organise science with society at a local level. It deals with discussing the institutional form that allows the exchange and co-construction of interdisciplinary projects with representatives of society on climate change mitigation or adaptation. How can the meeting of citizens and scientists be organised? How to build mutual understanding between scientists and non-scientists? How to integrate citizens' expertise in the research procedure? How to ensure the independence of the scientist with regard to political objectives? etc.

The second way of approaching the issue of science with society that OTECCA could implement consists in taking advantage of experience gained on successful projects. This feedback would enable a larger

audience to grasp the challenges encountered in concrete locally-developed projects and the solutions found in terms of changing practices and behaviours. This feedback will also highlight local success factors that can be replicated or adapted to other contexts. As an example, one of the results of the study carried out by two students of Political Science on the association "Les Petits Loups Maraîchers" (PLM) was to highlight the conditions, both social and political, which enabled its emergence on a local level and which should be met for this associative model to be replicated elsewhere. Additionally, through "Transition and Territorial Resilience: the case of Mouans-Sartoux" (RESET project), a group of researchers from OTECCA analyse from a multidisciplinary perspective how pioneering public policies of sustainable development were put in place in this municipality on the Côte d'Azur as early as the 1970s and their effects in terms of territorial resilience.

As a conclusion, while climate change is a global phenomenon, responses and solutions must be polycentric. The Observatoire de la Transition Ecologique et Citoyenne Côte d'Azur (OTECCA) constitutes a rich opportunity for stakeholders in the ecosystem of the Alpes-Maritimes area to join forces, and contributes to bring together a research community in socio-ecological transition stakes. Thus, it is a stepping stone for social as well as scientific innovation and a contribution for collective action to the fight against climate change.

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Our advocacy for sustainable seas

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Seas and oceans are complex ecosystems that support life on earth (climate regulation) and provide essential services to human societies. However, direct or indirect multiple anthropogenic pressures may impact the coastal areas and make the marine ecosystems vulnerable. The health of the seas and oceans has therefore become a crucial issue. The United Nations Decade of Ocean Sciences for Sustainable Development (2021-2030) aims to promote partnerships between all stakeholders, education and public awareness with the ultimate goal of removing the barriers to protecting the oceans and seas.

The ECOSEAS (Ecology and Conservation Science for Sustainable Seas) laboratory of Université Côte d'Azur has been involved for many years in programmes to protect and restore marine ecosystems, as well as programmes to monitor the impact of pollution (chemical, noise or harmful algae blooms), invasive species, the destruction of habitats and overexploitation of resources. Faced with the extent of the environmental disturbances observed, the time for action is now more than ever! We need to spread scientific knowledge, share research innovations and propose mitigation and adaptation solutions, in particular nature-based solutions. It is also urgent to raise awareness among citizens, especially school-age children, of the major challenges of protecting marine ecosystems.

1. Sharing innovations to improve knowledge

The researchers of the ECOSEAS laboratory are committed to sharing the innovations and data resulting from their research with different stakeholders at a local, national and international level, such as local authorities, fishermen, managers, sea users and citizens. Observation is essential to acquire reliable biological, ecotoxicological, ecological and socio-economic data. Results are intended to be disseminated and shared with the greatest number of people to contribute to the implementation of monitoring programmes and the sustainable management of marine ecosystems. For example, we are currently working on developing complementary biodiversity monitoring methods (environmental DNA and artificial intelligence), improving archaeozoological analyses to better understand today's environment, designing early warning tools for assessing and monitoring the biological and chemical quality of marine ecosystem, testing species distribution models under several climate change scenarios, and finding conservation-based solution for the implementation of Marine Protected Areas (MPAs). We are also conducting research on the trophic connectivity between artificial nurseries in ports and surrounding areas, in order to improve theses nurseries and facilitate fish recruitment in ports, and on harmful algal blooms and their associated toxins to bridge the gap between marine biodiversity conservation and food safety.

To assess the impact of climate change in the long term, it is essential to establish regular and reliable monitoring and observations, which will provide a long-term time series of data of great value to scientists around the world. It is our responsibility to monitor and make these observations, although we regret that these activities are rarely funded by grants or other public/private funding. These observations can be used to set up early warning systems for the appearance of non-indigenous species (fishes, macroalgae, toxic microalgae), to monitor the spatio-temporal dynamics of the quality of the marine ecosystems related to the evolution of different types of pollution, or to draw up risk maps according to different climate change scenarios.

As all of these data are intended to be shared, we are also developing reference databases, such as a database that lists all of the coastal artificial structures on the French Mediterranean coast and their impacts (www.medam.org; Bottin et al., 2022) and a database that lists all of the marine protected areas (MPAs) and marine reserves on the French Mediterranean coast (www.medamp.org; Bottin et al., 2021). Innovations can also be found in practices, such as the implementation of a toolbox for MPA managers (Hogg et al., 2019, https://fishmpablue-2.interreg-med.eu/).

2. Nature-based solutions to mitigate climate change and support marine ecosystem adaptation

Proposing solutions requires a good knowledge of the impacts of anthropogenic pressures (including climate change) on marine socio-ecosystems. ECOSEAS researchers are involved in various projects to assess the health of marine ecosystems (Di Franco et al., 2016; Rouane-Hacène et al., 2018; Vandenbussche et al., 2019; Di Franco et al., 2020; Mansour et al., 2020), the impact of climate change on fish populations and assemblages (Giakoumi et al., 2019; Schickele et al., 2021 a&b; Ben Lamine et al., 2022), and the impact of climate change on organisms, for example planktonic photosymbiosis (Villar et al., 2018).

The aim is to be able to propose mitigation and/or adaptation solutions to stakeholders. Nature-based solutions are both interesting in terms of their impact on biodiversity (restoration and preservation), and also in terms of reducing the effects of climate change. For example, MPAs are a powerful tool to protect ecosystems and increase their resilience. ECOSEAS researchers are involved in the design and monitoring of MPAs, but also in the promotion of sustainable fisheries (Ben Lamine et al., 2018; Ben Lamine et al., 2020; Zupan et al., 2018). In these projects, the researchers work in close collaboration with local authorities, MPA managers and fishermen.

Similarly, seagrass beds and marine forests are important elements in the structuring of ecosystems. They help to maintain a high level of biodiversity and food-web structure and contribute to coastal

protection. Several restoration and conservation projects for these marine forests are underway in our laboratory (Fabbrizzi et al., 2020). Researchers are developing protocols for restoring marine forests, which can then be applied by managers, particularly in MPAs. For example, they are working on the effect of climate change on the recruitment of forest-forming macroalgae species (Monserrat et al., 2022).
Moreover, the ecology of Posidonia oceanica wrack beds is of great importance (Bussotti et al., 2022a), as their maintenance on beaches can be a nature-based solution for preserving the coast from erosion. This is the subject of the ECOMED project and this aspect was developed as an educational experiment for secondary school students by scientists working in partnership with educators (Bussotti S. et al, 2022b).

3. Training the stakeholders and raising public awareness
As mentioned above, ECOSEAS researchers are involved in the development of innovations and are keen to share these processes with all those involved in marine environment (MPA managers, fishermen, associations, diving clubs and local authorities). Researchers are often interacting with these stakeholders and are sometime involved in training activities. Dialogue with all users is extremely important to obtain their commitment, facilitate compliance with the rules and improve decision-making processes.
As most researchers are also university lecturers, they can teach the results of their research, processes and technological innovations to their students, and train future decision-makers who are well-informed on these issues of marine ecosystem preservation.
Moreover, the laboratory staff are also involved in the Science and Society dialogue through their commitments and actions within the framework of the Observatory of the Ecological and Citizen Transition of the French Riviera (OTECCA).
Finally, as we are more careful to preserve what we know well, it is essential to raise awareness among all citizens, insisting on the education of the youngest, as they are the ones who will take over. Thus, several educational/citizen science projects are being developed in the laboratory in partnership with secondary schools. Other projects are underway with the members of diving clubs in the area. Researchers are also involved in creating content for the general public, such as books (Meinesz 2021) and comic books (https://thalassa-env.com/wp-content/uploads/2019/05/Pavis_Fishtales.pdf) or a toolkit for MPA managers (https://fishmpablue-2.interreg-med.eu/news-events/news/detail/actualites/a-governance-toolkit-for-ssf/).

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Student perspectives on environmental transition

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For those who may not be aware of it, COP27 implies that over 27 sessions have occurred since 1995 in the context of climate change action, mitigation and prevention. Unfortunately, we have still not seen a meaningful effort by large corporations and governments to develop and commit to sustainable practices. In light of this information, we are calling for this COP to result in an effective and meaningful discussion that leads to action now.

As aspiring marine scientists, we prefer not to be categorized in the same group as the youthful, screaming environmentalists that we see in the press, on television and through social media. We do not side with radical groups that seem to seek confrontation instead of collaboration, with slogans in which one can read between the lines the infamous "either you are with us or against us". In many ways, we feel this may be trivialising climate change, while also instilling resentment towards these issue in the eyes of the public.

Instead, we consider ourselves scientists, who have set out with the goal of realistically solving the problems we collectively face in consideration of sustainable economic growth and social equity. In many respects, many of us understand that change is not something that occurs overnight, but rather requires a gentle transition from the current archaic system we have accepted in the past. In other words, we acknowledge that the transition from black to white may need to go through a wide range of greys.

In our current position, as the next generation, we are not calling on society to completely do away with its necessary means of transportation such as airplanes or large merchant ships that transport our goods worldwide. Similarly, we recognise that we depend on nuclear energy and cannot entirely eliminate our dependency on coal, natural gas and oil. However, it is essential that we accept that this is unsustainable in the long term and has led us to the largest threat known to date by humankind, quite possibly leading to the sixth mass extinction on Earth that could include humans.

In our eyes, decision-makers are among the main levers for generating large-scale ecological action. A successful ecological commitment must include the development of new technologies centred on communication and education. These tools have been and continue to be powerful ways of spreading information and creating awareness. With that said, it is important that through political action, we further develop technologies that encourage the implementation of new, innovative ways of raising society's awareness of the environmental crisis.

However, we must not forget that the responsibility for climate change is collective as much as it is personal. Accountability for this disaster not only rests on governments and large corporations, but also on each one of us. Let's remember that change can begin even in the slightest action and can come from anyone regardless of origin, faith or gender. In other words, simple changes in our everyday lives may have positive impacts on a worldwide scale. For example, according to the US Environmental Protection Agency (2020), committing to public transportation could reduce our individual greenhouse gas (GHG) emissions by over 50%. As a result of our public transportation commitments, governments could be responsible for supporting more efficient, more comfortable and more economical transportation systems that accommodate larger populations.

Additionally, instead of buying new clothes, we can turn to thrift shops or second-hand stores in an effort to avoid supporting fast fashion while also reducing our ecological footprint. Creativity is vital when it comes to environmental solutions. When it comes to giving life back to our old clothes, we can also exchange them or donate them. Moreover, let's not ignore the huge impact of meat consumption in the climate crisis. The production of a regular 171g steak consumes as much as 2,498 litres of fresh water (GRACE Communications Foundation, 2022). The production of a Mcdonald's Big Mac leads to the emission of 2.35 kg of CO_2, the equivalent of driving 12 km on a UK petrol car (Webber, 2021). We understand that completely eliminating meat from our diets is unrealistic, however, one meatless day per week can save the same amount of emissions as driving 560 km per year (Conzachi, 2021).

Furthermore, supporting local actions can result in significant positive consequences in the fight against climate change. Encouraging one another to be conscious about our impact on the planet and our future is vital, not only to promote climate solutions but to close the ideology gap between the current youth and older generations. Although lifestyle changes that require effort and transition may be challenging, they should not take away from the idea that our archaic actions are hurting others and destroying our planet. We aim to secure the future for ourselves and future generations collectively, while also ensuring we do not disrespect the ideas and traditions of those before us.

In conclusion, we are not expecting to wake up tomorrow in a world where climate change has never existed, but we do want our ideas and concerns to be considered for their utmost importance. Our strong desire is to see real commitments and tangible actions toward sustainability set by governments, large corporations and individuals in the near future. We are prepared to dedicate our lives to alleviating the negative impacts through science. We can only expect that during this year's COP, we will finally be able to get excited about the imminent change we will see as a result.

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Student Position Paper: POLYTECH Nice - Sophia, Université Côte d'Azur

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Who are we?

We are students of Polytech Nice-Sophia concerned by current environmental issues and committed to finding solutions at our university's level. We are members of a student association, the Humanitarian and Environmental office, which initiates projects related to ecology and soli-darity.

Our thoughts

As students of Université Côte d'Azur, we have noticed the commitment of the teaching staff in the educational content they propose. We effectively have courses on environmental issues and training to make us aware of the impact of human activities on our planet. However, we would like to see these issues included more concretely in the subject matter of our training. This would help us to foresee the consequences of our future profession on the environment and possibly limit them. For example, implementing workshops or group projects on environmental subjects rather than theoreti-cal classes, would make students more involved. We also think it would be interesting to involve students in the calculation of their own carbon footprint as well as that of the school to raise aware-ness of the need for collective energy efficiency.

We are also grateful to our university for enthusiastically supporting ecological projects led by students, especially those set up by our association. Thanks to this support, we had the opportunity to plant trees on our campus after it was certified by the national bird protection league. We were also able to promote alternative means of transportation, and our future projects include installing a gar-den and insect houses on our campus.

In addition, our university is also implementing sustainable measures such as the installation of garbage sorting bins on campus, the upcoming installation of a compost bin, and collection points for used electronic devices. In addition, our engineering school has a true policy of energy preservation that includes the installation of solar panels and the renovation of premises. This could be improved especially as regards digital pollution, because we are submerged by e-mails that pollute our mailboxes and are not even always read. It could therefore be relevant for the university to share information more efficiently, by setting up an announcement wall, for example.

The contribution of the LINE laboratory to education on prudent uses of digital technology through the prism of educational innovation

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I. Context and Issues

Climate change is leading to a very strong diffusion of information on responsibility and prudence. Many people are currently advocating for education on prudent technology use. In this context, at the Laboratoire d'Innovation et Numérique pour l'Education (LINE), a research unit that works in the field of Educational Sciences, we are developing a reflection on education for, by and about more responsible uses of digital technology (Descamps, Temperman, De Lièvre, 2022). Thus, our research unit is developing a reflection on innovation in the educational field that questions both the processes of acceptance and integration of digital tools and the conscious change that shapes new teaching and learning practices.

We are in fact faced with a tension: on the one hand, to encourage the development of digital education in the perspective of a transformation of the contents and modalities of teaching and training, and on the other hand, the need to raise the question of digital prudence, to make uses more responsible and to develop a critical and creative reflection on digital technology that integrates this dimension. For us, prudence implies an awareness of the educational stakes in order to educate learners to a strong conception (Pellaud and Eastes, 2020) in order to think about their uses with a systemic and creative thinking. Considering the development of educational digital uses in this way allows us to overcome the tension (development-prudence) and to design conscious uses. Consequently, it is a question of developing the potential of digital technology while educating people to use it in a prudent and reasoned way, making choices that are relevant to the teaching and training issues at stake. In other words, we believe that there can be no development of digital education without addressing the issue of prudent, responsible and ethical uses.

In order to take this dimension into account, our research activities develop a mixed methodology that allows us to articulate the reflection on digital uses in a sober context with our critical approach to innovation.

Our aim is to understand how to accompany innovation and practice transformation actions while at the same time teaching prudence.

II. Areas of Work

Our contributions focus on recent research developed within LINE that contributes to a critical approach to innovation (Dias-Chiaruttini, 2021).

II.1. Documentation of Practices

This dimension consists in identifying, observing and analysing emerging activities through the prism of their transformative potential. We know, in this respect, that several FabLabs already offer extracurricular activities and are fairly representative of a shared culture around the idea of useful, sustainable and accessible technology (Parmentola et al., 2022). The scientific mediation community, especially in our region, is particularly fertile for building a reflection on digital prudence education and therefore to identify, observe and analyse their transformative potential. Finally, the didactic framework of these activities on and for prudence and vigilance in digital uses could be put to the test in the classroom, as envisaged, for example, by some researchers at LINE (Heiser, Romero, De Smet, Faller, 2020).

II.2. Critical Understanding

In the context of sobriety, we analyse as closely as possible the traces of the actors (teachers, mediators, students or participants) by reconstructing their lived experience (Heiser, 2019). And the transformative process is played out precisely during the lived experience, which also refers to a reflection on teachers' practices and how to accompany their professional development (Brunel and Heiser, 2019). From this point of view, we can accompany the training of stakeholders, connecting it with research and ensuring that we develop their critical understanding of the uses of digital technology in a context of prudence.

II.3. Ethical dimension

This is a question of taking into account certain intrinsic characteristics of digital uses, to better connect the question of prudence with that of awareness of the finitude of the planet. As Villalba (2016) points out, it is a matter of making people aware of the problem (i.e., certain unreasonable uses of digital technology), of the cost, of the inequalities and of certain deleterious uses (Courbet et al. 2020) in order to bring individuals to an accepted prudence. This axis is concretised by an inventory of learning, practices and attitudes related to this unconstrained prudence.

These three axes constitute the framework of our reflection through the prism of innovation. They allow us to address the issue of climate change by highlighting behavioural changes thanks to the specific light of the educational science

III. Perspectives

Within LINE, we wish to create an observatory of pedagogical practices (which necessarily leads us to be interested in their implementation within cultural and scientific mediation), allowing for the documentation of emerging practices. We plan to develop research-designs to conceive activities on the prudence and vigilance of the uses of digital technology by specifying that they are controlled activities and thus specifically planned setting up research.

In particular, we analyse existing pedagogical devices through several specifically adapted

methodological protocols: non-participant observations, interview grids around themes such as the design of pedagogical sessions related to the digital ecosystem as a tool/object of study/subject to be regulated, or the use of camera glasses, which allow for subject feedback on his or her own experience (Heiser, 2019).
These methodological tools allows us to develop an understanding of the subject and to verify the efficiency of pedagogical activities aimed at teaching digital prudence.

We are thus part of a systematic process to:

- **Observe** pedagogical practices related to responsible digital technology (low tech, digital prudence)
- **Create and test** pedagogical practices related to digital responsibility by evaluating creativity (power to act in a world facing climate change)
- **Circumscribe** the lived experience of participants during transformative activities
- **Modell learning-by-doing approaches** from a didactic point of view
- **Analyse** the innovative character of pedagogy-by-doing using the dynamics of work within the LearningLab network of the Inspé de Nice
- **Transfer** models of experiences in the field of transformative education and Education for Sustainable Development (ESD)
- **Recommend** professional practices and rules that take into account the ethical aspect in order to promote the acceptability to stakeholders

On the basis of this reflection and the research activities carried out, we believe that we can enrich Université Côte d'Azur's contribution to the political, social and scientific debate on the stakes of education in the prudent use of digital technology that does not slow down the transformation of education and training, but rather makes the participants responsible for their use and efficiency.

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The critical need for interdisciplinarity in higher-education to address the multifaceted problems of a changing world

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A society in denial of science...

The general public has mixed feelings about science. They seem to have high expectations of the science of meteorology to tell them what the weather will be like the next day. But they seem to be detached from the science of climate that warns them of the weather at the end of the century. For some, science is just one possible voice among many (Mitroff & Feryerabend 1976, Blancke & boudry 2021). Our policy makers are supposed to rely on scientific expertise to provide them with evidence on which to base their policies. But science is slow, contradictory, and full of uncertainties, and the Covid experience has shown that the population rejects these constraints (Battiston et al. 2020, Provenzi & Barello 2020). As a result, people have to choose between scientific information based on long studies and peer-reviewed evidence, and pseudoscientific opinions sometimes based on irrational beliefs (Teovanovic et al. 2020).

And yet, the public is becoming increasingly educated. In France, in 2013, there were eight times more students in higher education than in 1960. Today, 70% of high school students obtain the baccalaureate, compared to 10% fifty years ago. In the OECD in general (and in France in particular), 40% of people of working age (25-64 years old according to the OECD) have a higher education degree, and the proportion is ten points higher for the youngest of them (25-35 years old).

So why is science so discredited by the public? Why does the public think they know instead of listening to those who study? Perhaps there is one more step to take. By improving public education in general, the public may think they know what they are just scratching at. Perhaps this is an illusion of control, a cognitive bias (Dror 2020). Perhaps science is still too far out of sync with society.

... but a society full of science

Science feeds society, especially in the context of climate change. The physical causes are well known, and are rather clear and precise, and even if the consequences on biology are still subject to precautions, the impacts on the socio-economic sphere are inevitable. In this stressful context, and with limited resources, what strategy should be adopted? Scientists and decision makers should get together around one table.

The example of coral reefs is quite striking. The latest IPCC report predicts their widespread disappearance by the end of the century, even if we accelerate our mitigation to meet the Paris Agreement targets (70-90% decline at +1.5°, 99% at +2°, Gattuso et al. 2014). So why continue to protect reefs that are likely to disappear in the coming decades anyway? Because fighting for the protection and restoration of coral reefs contributes to the development of local communities, and the longer they last, the better. Indeed, while the share of coral reefs in the GDP at the national level is generally limited to 5%, it can reach over 25% at the community level in Vanuatu and Fiji (Pascal 2011, Laurans et al. 2013). Thus, coral protection and restoration should not only be considered as a solution against coral loss but as a solution for the sustainable development of local communities. As the UN Sustainable Development Goal emphasizes: climate action, food security, sustainable value creation and addressing inequalities are fully intertwined.

Many stakeholders propose to help these communities find solutions to their development problems, such as overfishing. In Indonesia, fishing with explosives is a practice imported by Westerners that has largely destroyed coral reefs (Hampton Smith et al 2021). For the past ten years, the French NGO Coral Guardian has been helping local communities to change their model. By rebuilding their reefs, they are rebuilding a natural capital from which they can recreate a value chain. This initiative is successful because of a brilliant vision, the interweaving of socio-economic and environmental issues, with the help of science. This comes in contrast to other conservation efforts that make the mistake of focusing solely on environmental issues, sometimes without considering science and the local communities.

The urge for interdisciplinarity in higher education

Climate change is creating environmental challenges on a magnitude never seen before in our civilization. In this context, the fight against climate change and for the environment must never lose sight of the need for the sustainable development of populations. Now, we must train those who will find the solution to these multi-faceted issues. Not only must we train rigorous scientists capable of understanding the current global issues and finding solutions. But we must also train them to contextualize these solutions in a very diverse socio-economic fabric, for the benefit of the sustainable development of human communities, each with different local challenges.

It is therefore crucial to create a fertile ground between disciplines, so that future experts in natural, social and economic sciences work together during their studies. Our future decision-makers must be able to take into account all the multiple aspects of the same problem. We must train tomorrow's scientists to always be ready to use their critical thinking skills to study facts, and to be open to the richness of interdisciplinarity.

Perhaps then our citizens and decision makers will regain faith in science and will be able to turn to those who promote scientific disciplines to find solutions to their challenges in a changing world.

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The Space, Environment, Risk and Resilience Academy, a tool to foster climate change research initiatives

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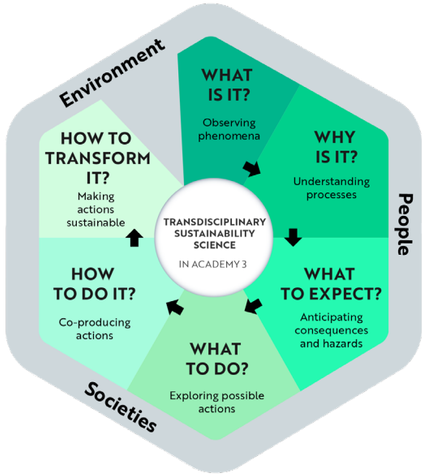
I. Positioning

> *The "health" of our planet and of its broader ecosystems (natural environments, biodiversity, humans, cities, etc.) figures among the greatest concerns of our modern era.*

The "health" of our planet and of its broader ecosystems (natural environments, biodiversity, humans, cities, etc.) figures among the greatest concerns of our modern era. Natural and anthropogenic hazards are increasingly threatening the Earth and life, and a major challenge of the current century is to provide our societies with strategies to face the threats, reduce the risks, and promote the sustainable well-being of ecosystems. Despite immense progress in understanding natural and human environments, the diversity, complexity, and interconnections of ecosystems remain difficult to fully describe. And despite international institutions, state policies and local initiatives, conflicting interests at all scales contribute to hamper our capacity to manage our world in a more sustainable manner.

About 10 years ago, the concept of "planetary boundaries" was proposed to pave our way towards global sustainability [1]. A planetary boundary is defined as a limit that must not be transgressed if humans aspire to live in balance with their universe. Nine planetary boundaries were defined: climate change, ocean acidification, stratospheric ozone depletion, atmospheric aerosol loading, biogeo-chemical flows (interference with P and N cycles), global freshwater use, land-system changes, rate of biodiversity loss, and chemical pollution. Each boundary has a threshold whose transgression might plunge humanity and Earth into an irreversible situation. In addition, most boundaries are interconnected so they form an intricate pattern of interrelated hazards. The planetary boundary framework demonstrates that the current and future challenges we are facing are complex, diverse, and defined within an intricate four-dimensional system including space, time, type of risk, and resilience. A few years later, threats from novel entities defined as "new substances, new forms of existing substances and modified life forms" [3] were introduced, with an emphasis on chemical pollution [2].

The *Space, Environment, Risk and Resilience* Academy is an academic tool of Université Côte d'Azur created in 2016 to foster research initiatives in transdisciplinary research and address scientific questions in the broad field of environmental risks. The Academy has a core interest in the relationships and interconnections between humans, societies, ecosystems, and the Earth. This encompasses a wide range of multidisciplinary fields including all the aspects of natural sciences and social sciences. The objective of the *Space, Environment, Risk and Resilience* Academy is to create a new paradigm of inter- to transdisciplinary science where hazards are considered holistically, and risks described globally with all their components.



Since its inception, the Academy has laid down the main cornerstones for transdisciplinary research and training in hazards and risks at Université Côte d'Azur, fostering and supporting about 60 collaborative projects. These include the impact of endocrine-disrupting compounds on human health, marine noise in the Ligurian sea, nuclear risk perception and management, and the analysis of the effects of Storm Alex (2020) in the Alpes-Maritimes region to name a few.

II. Fostering research initiatives in the scope of *Space, Environment, Risk and Resilience.*

One of the main threads of the Academy is to address environmental and societal issues in line with the Sustainable Development Goals (SDG) of the United Nations [4]. This requires fostering new approaches that overcome the current fragmentation of research, integrating scientific knowledge across different disciplines and stakeholders, and co-creating scientific questions and projects together with specialized research groups. This calls for the development of transdisciplinary research that fuses natural and social sciences and medicine and integrates scientific experts, practitioners, and civil society. To reach this objective, the Academy is promoting integrated projects and approaches spanning a continuum from fundamental observation (*what is it?*) and scientific understanding (*why is it?*), to anticipation of consequences and hazards (*what to expect?*), exploration of coping strategies (*what to do?*), co-production of management responses (*how to*

do it?), and design of sustainable development pathways (*how to transform them?*). The Academy is also fostering scientific exchanges beyond specific scientific skills in order to favour interdisciplinary initiatives. We believe that only such an integrated transdisciplinary approach can help us understand natural and human environments, decipher their complex interactions, and protect them durably.
The Academy is fostering the construction of projects (scientific and applied projects, training programs, workshops, dissemination projects, etc.) that are deliberately transdisciplinary and integrated with the SDGs in order to pave the way towards sustainable development. Projects are invited to include a reflection on the costs and benefits of the proposed actions at different spatial and temporal scales and link scientific observations with possible guidelines. More specifically, the *Space, Environment, Risk and Resilience* Academy encourages projects within the framework of five thematic topics that are also linked to clusters of SDGs:

- Anthropogenic hazards for human health, environments and global changes (SDGs[4] 3, 6, 13)
- Natural hazards and impacts on environments, cities and societies (SDGs[4] 11, 13)
- Energy- and resource-related environmental challenges (SDGs[4] 7, 12, 15)
- Threats to oceans and coastal areas (SDGs[4] 14, 15)
- Risk assessment and management in relation to smart cities and territories (SDGs4 11, 12)

Finally, the Academy is promoting transdisciplinary scientific exchange by organizing a yearly seminar on questions of societal interest like *Risk, Resilience and Societies*. These seminars gather scientists from fields that are usually disconnected and rarely in dialogue; they therefore link disciplinary skills with open questions that require a transdisciplinary approach.

III. Training at the Master level.

The *Space, Environment, Risk and Resilience* Academy has developed an MSc specialized in addressing environmental hazards in the same transdisciplinary approach that drives our support to research. The MSc Environmental hazards and risks management (https://univ-cotedazur.eu/msc/environmental-hazards-and-risks-management) provides skills in risk management, and more particularly in risk modelling, to better predict and manage environmental hazards and risks. The program is project-oriented and based on specialized modules dealing with common hazards and risks: earthquakes and tsunamis, soil degradation, land cover change, flooding, mass movements, harmful algal blooms, and forest fires. Students therefore acquire a broad view of common environmental hazards and modelling tools in order to predict risk evolution and potential mitigation strategies. On completion of the degree, graduates have a comprehensive understanding of risk management and advanced technical skills in Geographic Information Systems, remote sensing, and programming in Python and R. This new program will be entering its fifth year in September 2023, and it has attracted students from about 30 countries so far. The MSc aims to train a young generation of thinkers capable of anticipating and mitigating a wide range of natural hazards in a multidisciplinary approach.

IV. Contribution

The research and education promoted with the support of the *Space, Environment, Risk and Resilience* Academy is thus rich and diverse and scientifically and socially significant. Since its creation in 2016, it has opened the door to new collaborations outside the usual fields of expertise of the researchers, both in France and internationally. As a result, a sense of collective concern has emerged in our community which shows the necessity for innovative observations, research, instrumentation, and actions at various levels, from individuals to policy-makers, including scientists and the general population. This may be the only way to develop efficient resilience strategies for humans and the world's ecosystems.

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Target 13.4

Implement the un framework convention on climate change

A call for a climate change-centred systematic approach by the BRICS development banks

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"We are at a defining moment in history - one which calls for bold, fast and wide-ranging collective action if we are to limit global warming and protect our fragile planet."[1]

Jin Liqun, President and Chair of the Board of Directors at AIIB

The demand for infrastructure investment is exponentially growing in developing countries [2], and it already amounted to 820 billion US dollars per year over the period 2014-2020 [3]. Since the developing countries are unable to provide these massive funds, several international financial institutions, along with other stakeholders (such as commercial banks, trust funds, companies and NGOs) are playing a dominant role in filling the gap caused by this lack of financial resources. In particular, Multilateral Development Banks (MDBs) are channelling an important part of the funding dedicated by the States to this specific purpose. At the same time, climate change and global warming are accelerating at an unprecedented pace [4], calling for substantive action, especially by climate finance, to remedy or at least mitigate their effects. Since 2015, year of adoption of the Paris Agreement, MDBs have continuously supported developing countries in the accomplishment of their objectives [5] under their own National Determined Contributions (NDCs). As they reported in a high-level statement in 2019, MDBs, and particularly the New Development Bank (NDB) and the Asian Infrastructure Investment Bank (AIIB), as co-signatories, are committed to helping their clients deliver on the goals of the Paris Agreement [6]. They were also signatories of the joint statement by MDBs at COP26 [7].

The main purpose of this analysis is to provide a few insights on the links between NDB and AIIB [8] and climate change adaptation and mitigation, which leads to contrasted findings. Formerly, development finance was structured around one 'universal' US-led Bank, the World Bank (and more particularly IBRD and IDA, its public-loaning institutions), and several regional and subregional Banks. But the progressive changes in international relations and the growing place of emerging markets and developing countries have created a paradigmatic shift. Nowadays, in a context of counter-institutionalization [9], governments of the BRICS States (Brazil, Russia, India, China and South Africa) have established the NDB and the AIIB. Both of their Articles of Agreement, adopted

in the mid 2010s, affirm their affiliation to global and regional development finance institutions, and embrace sustainable development as a goal.

Yet, the actual problem is a developmental one: on one side, development projects are essential to meet the needs of developing countries; on the other side, the more these huge projects take place, the more climate change adverse effects intensify [10]. In this sense, MDBs can be considered as part of the problem. To make sure that they are also part of the solution, different tools are in the hands of these financial institutions. These complementary actions are required to ensure an adequate consideration of the climate change challenges in the overall scope of their activities: prioritizing climate change mitigation and adaptation projects in NDB's and AIIB's respective portfolios, and adopting a cross-cutting, mainstreaming approach to climate change issues in every project funded.

The most important tool is corporate strategy. Most of the MDBs promote a green turn in their approval process, especially since 2015 and the adoption of the Paris Agreement. Each institution has individually committed to support increased climate finance levels over time, with an expectation of a collective total of at least 65 billion US dollars annually by 2025 [11].
For AIIB, it became more precise when its Management issued a commitment on October 26, 2021, that the Bank 'would align their operations with the goals of the Paris Agreement by July 1, 2023' [12] and that 'it would target at least a 50% share of climate finance in actual financing approvals by 2025' [13].
For NDB, the 2022-2026 General Strategy, endorsed by its Management on May 22, 2022, contains a commitment that NDB will 'dedicate 40% of its total volume of approvals to projects contributing to climate change mitigation and adaptation' [14]. In the 2021 Annual Report, another big figure is mentioned: the development results of the projects financed by the Bank in 2021 are expected to prevent 7.5 million tonnes/year of CO2 emissions[15].
This race to the top is a good signal of a desire to tackle climate change, but a problem arises from the high percentage of climate finance, and is found in what is left unsaid: What about the rest of the projects?
A striking illustration of this ambiguous posture can be seen in the latest projects approved by NDB's Board of Directors. Recently, the Board approved the Qingdao Metro Line Six (Phase I) Project [16], designed to improve mass public traffic with a subway line, whose expected benefits specifically mention 'emission reduction such as CO2 emissions' [17]. Conversely, Chinese projects approved in July 2022, such as the Lanzhou Zhongchuan International Airport Phase III Expansion Project [18], and the Xi'an Xianyang International Airport Phase III Expansion Project [19], are explicitly driven by the expected increase of annual passenger and cargo throughputs [20].
While these projects might be crucial for regional or national short-term development, their consequences for climate will certainly be deleterious. It is not possible to delay radical change in the economy and in the society anymore. Firstly, targets should keep on being updated. Secondly, alternative ways of travelling for the passengers and movement of goods must be chosen over CO2 emitting ones. In a broader sense, projects with a smaller gas-emitting effect should become the first choice automatically to mainstream climate action.
Besides, in the already-happening scenario in which these Banks expand their activities to other sectors than infrastructure, the trend to strengthen the institutional and national capacities of the Borrowers reveals hypothetical loopholes in their approach. Even if the digital transition seeks to build a more efficient administration, questions result from the increased use of digital systems in health and education. In fact, without proper training about digital sobriety, abusive use of digital technologies can lead to massive waste of energy [21]. For an example of good practice, in December 2021, AIIB's Board of Directors approved co-financing of the Rwanda Digital Acceleration Project [22]. In this project, a two-step requirement is detailed: specification of energy efficiency requirements in procurement packages [23], and incorporation of high energy-efficiency requirements in all bidding documents for all the equipment [24]. In the end, the issue remains the same, i.e., a proper and adequate assessment of the key risks of a project is crucial to prevent environmental harm and address climate change.

Another tool is the common approach of MDBs with respect to Paris Agreement alignment. In order to comply with the objectives of the Paris Agreement, MDBs jointly crafted a Paris Agreement Alignment Approach [25], composed of six complementary building blocks: alignment with mitigation goals (BB1), adaptation and climate-resilient operations (BB2), accelerated contribution to the transition through climate finance (BB3), engagement and policy development support (BB4), reporting (BB5), and alignment of internal activities (BB6). To put it in simple words, a highly-sophisticated process has been developed for BB1 and BB2 to determine if a project is aligned or not with the objectives set in the Paris Agreement. Since the screening process [26] is often oriented to preserve country ownership and therefore reduces the scope of the assessment required from the Borrower, a possible track to foster consideration of climate change adaptation and mitigation might be to formalize an ex-ante conditionality for every project, based on the requirement to be aligned with the Paris Agreement.
As it is still a technical note, parts of the methodology to establish Paris Agreement alignment [27] of the projects might keep on evolving. Nonetheless, this methodology is meant to provide guidance for the achievement of NDCs and Long Term Strategies (LTSs) to the Parties of the Paris Agreement. But as it is standing now, this note offers short-term solutions that might actually worsen the long-term situation. For example, the manufacture of electric vehicles is included in the table of Annex 1: Activities considered universally aligned or not aligned with the Paris Agreement's mitigation goals, whereas the extraction of rare metals, essential for the batteries is highly energy-consuming and polluting [28], even if the use of electric cars might reduce CO2 emissions. The hypocritical unwillingness to recognise the long-term impact of the Anthropocene needs to be swept away, otherwise these solutions will only delay the problem of human beings' exploitation of the earth and its consequences [29].
The legal framework of MDB activities also contains a valuable tool: environmental and social frameworks or policies. These policies are meant to prevent interconnected phenomenon, such as environmental harm and pollution [30], but also climate change itself, during the whole cycle of a project. However, the binding nature and the effectiveness of these framework policies, operating in a managerial space, remains clearly debated in the literature [31], even when a comprehensive environmental assessment of the risks induced by the project has been conducted [32]. For instance, climate change is explicitly included in NDB's environmental and social policy [33], regarding the screening by Management [34] and environmental assessment requirements of the Borrower [35]. These policies could create a crucial change, if the institutions agreed to formally recognize their binding nature and would encourage the practice of keeping environmental and social exclusion lists to stop financing projects generating high-emissions of CO2 [36].

In conclusion, one can say that the problem is not awareness anymore, but lack of radical action. NDB and AIIB have reframed the global financial context and are key actors for climate finance, but they clearly need to use their emerging influence to support and not undermine the Paris Agreement's purpose. The avenues for reflection presented in this paper could provide guidance in this process. As Ken O'Flaherty, United Kingdom's COP26 regional ambassador for Asia-Pacific and South Asia stated unambiguously: 'All MDBs will need to make efforts to ensure (...) that Paris alignment is more than just a slogan, and that it is a real way of doing business.' [37] More broadly, a counterintuitive point of view to climate finance and sustainable development as it is understood today could be to lift the taboo of degrowth [38] for developed countries, and promote low-techs worldwide, in accordance with the principles of equity and common but differentiated responsibilities and respective capabilities.

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Governance issues and dissensus about 'climate security' in the United Nations

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I. The 'climate security' approach

In recent years, the links between climate change and peace/security have been increasingly recognised and have gained significant attention in many international fora and institutions, constituting a hot topic of the international agenda. While some impacts of climate change on security are direct and visible, others are more complicated and difficult to assess.[1] All these interconnections have now been summarised in the United Nations (UN) system by a specific concept: 'climate security', which consists in integrating climate science and peace/security issues. The concept is at the crossroads between the international action for climate and the international action for peace; in particular, it addresses how to integrate climate change adaptation initiatives and peacebuilding, conflict prevention and 'sustaining peace'[2] objectives. Logically, this 'climate security' approach has gained much importance in the UN system, raising disagreements between States on the governance of this strategic issue.

II. UN climate security initiatives beyond UNFCCC

In the UN Organization, the topic of climate security has been addressed by diverse institutions since the mid-2000s. Significantly, the Department of Political and Peacebuilding Affairs (DPPA), in charge of preventing conflict and building sustainable peace around the world, has included in its activities the impact of climate change on peace and security. The DPPA thus promotes approaches that combine peacebuilding with resilience and adaptation efforts, financing for instance climate-sensitive peacebuilding projects around the world. [3] The climate security approach is also followed by other UN institutions, in particular the United Nations Environment Programme (UNEP) and the United Nations Development Programme (UNDP). DPPA, UNEP and UNDP launched together, in 2018, a joint initiative named the 'Climate Security Mechanism' (CSM). Its mandate is to strengthen the capacity of the UN system to analyse and address the adverse impacts of climate change on peace and security, and thus develop climate sensitive approaches in the UN sustaining peace action. [4]

These efforts, among others, [5] are undoubtedly significant. Are they the implementation of a global common vision about climate security? It is interesting to note that Germany and the Republic of Nauru jointly formed a 'UN Climate and Security friendship group' in 2018. It aims to develop cooperative solutions 'for the impact of climate change on security policy, raise public awareness, and boost the involvement of the United Nations in this area'. Even though the number of participating States increased from 27 founding members to 59, reflecting a growing convergence, this is only a few of the 193 UN Member States.

While security issues are not directly considered in the framework of the United Nations Framework Convention on Climate Change (UNFCCC), [6] it appears even more critical to analyse the way the Security Council (SC) addresses climatic aspects while 'maintaining international peace and security' on behalf of the international community. The impact of climate change on the maintenance of international peace and security was debated for the first time at the Security Council in 2007, after a vigorous exchange about whether such consideration was appropriate. A SC Presidential Statement was adopted in 2011 about the CS' consideration of the effects of climate change. [7] The SC also inserted in some resolutions about specific situations various references to climate, establishing a direct link between climate and security issues. [8] The resolution 2349, adopted unanimously in 2017, is emblematic in this regard, as the first recognition by the SC of the link between climate change and instability. [9] In 2018, the SC added environmental factors in the mandate of the peacekeeping mission in Mali (MINUSMA). Following that, the effects of climate change have been taken into account in SC resolutions on many other specific situations. [10]

However, a recent episode has called into question this progress made by the SC over the past 15 years.

III. 2021 clash in the Security Council: irreconcilable visions?

In December 2021, Niger and Ireland co-sponsored the project of a SC thematic resolution, [11] supported by 113 UN Member States, promoting the integration of climate-related security risk into UN conflict-prevention strategies. The aim was in particular, under the 'sustaining peace' approach, to take into consideration the risk of conflict relapse due to adverse effects of climate change. The draft resolution was rejected on 13 December: while 12 SC Members voted in favour of the text, India and Russia voted against it and China decided to abstain. Despite the overwhelming majority in favour of the text, the negative vote of Russia (permanent member of the SC with veto) was sufficient to block its adoption.

This resolution would not have changed the legal prerogatives of the SC. [12] But this episode has a deep political significance, as revealed by the motivation of their votes by the three States: [13]

- China stressed the need to avoid securitization of climate issues. The draft resolution did not address the main aspects of the reduction of greenhouse-gas emissions down to net-zero emission and common but differentiated responsibilities. Instead of stating that developed countries have a responsibility to help build capacity and resilience in developing countries, the text 'could allow developed countries new excuses to shirk their historical responsibilities and commitments'.
- According to India, the SC is not the place to discuss the issue. The draft resolution 'seeks to obfuscate the lack of progress on critical issues under the UNFCCC'. Such a SC resolution would constitute 'a step backward from collective resolve to combat climate change', especially since UNFCCC is a much more democratic place than the SC.

- In the same vein, Russia also stated that the draft resolution represented a step back in trying to fight climate change and an attempt to divert attention from genuine deep-rooted reasons for conflict in some countries on the agenda. Such debates should be carried out in the appropriate forum: the UNFCCC. Climate change is a scientific and socioeconomic issue which should not be turned into a politicized question.

In sum, even if the draft text recognised the central nature of UNFCCC, those States criticized this proposal in that it would establish a process separate from the UNFCCC and create a diversion. This rejection has thus revealed the depth of a long-lasting dissensus concerning the governance of climate security. [14] We can regret this step backward and hope that it does not announce that climate issues will no longer be considered by the SC in the maintenance of international peace and security in specific situations. The SC has an exclusive mandate in this respect, and is thus to play a decisive role, which is complementary to and supportive of other aspects considered in other instances. [15] We can recall what the UN Secretary General wisely stated at the SC session on climate change in July 2011:
'The Security Council can play a **vital role** in making clear the link between climate change, peace and security. The Members of this Council bear a **unique responsibility** to mobilize national and international action to confront the very real threat of climate change and the specific threats to international peace and security which derive from it.'

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5 For example, courses by the UN Staff College on 'Climate Sensitive Programming for Sustaining Peace'.

6 It is remarkable that neither 'peace' nor 'security' appear in the list of the 'topics' of the UNFCCC on its website.

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9 The SC 'Recognises the adverse effects of climate change and ecological changes among other factors on the stability of the Region(…) and emphasises the need for adequate risk assessments and risk management strategies by governments and the United Nations relating to these factors'.

10 List of special political missions and peacekeeping operations.

11 A thematic resolution is a generic resolution adopted about a global issue, without being related to a specific situation. This practice of the SC is well established. For example, such resolutions have been adopted about the protection of children or women in armed conflicts, youth in conflict prevention and resolution.

12 The main measures proposed were to ask the Secretary General to submit a report on the security implications of the adverse effects of climate change in countries or regions under his consideration, to encourage peacekeeping operations to take into account, within their existing mandates, the security implications of climate change, and to invite all relevant stakeholders to cooperate to enhance knowledge of climate-related security risks and to develop strategies for conflict prevention.

13 Minutes of the 8926th meeting, 13 December 2021: S/PV.8926. See also arguments of Kenya.

14 As highlighted by Russia, 80 UN Member States did not support the draft resolution (S/PV.8926, p. 9). On the controversies about the role of the SC, see P. Palchetti, « Débattre des changements climatiques au Conseil de sécurité : pour quoi faire ? », Questions of international law, 2022.

15 It is worth reminding that in a 2009 resolution (63/281 adopted by consensus) on 'Climate change and its possible security implications', the UN General Assembly 'Invite[d] the relevant organs of the United Nations, as appropriate and within their respective mandates, to intensify their efforts in considering and addressing climate change, including its possible security implications.'

Target 13.5
Promote mechanisms to raise capacity for planning and management

Environmental migration as economic and non-economic losses: how to meet the cost of inaction

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"(…) Right in all of us. Trust this earth uprising.
All of us bring light to exciting solutions never tried before
For it is our hope that implores us, at our uncompromising core,
To keep rising up for an earth more than worth fighting for."

Amanda Gorman [1]

"Decades of procrastination have transformed what could have been a slow transition to a carbon-neutral society into what will now have to be a more abrupt one".[2]

The climate change-migration nexus is one of the major challenges our societies will face in the coming decades. The impacts of climate change and environmental degradations on people and communities are being studied by various disciplines, sometimes through interdisciplinary research, and have revealed dynamics and difficulties in addressing the issue. Most of the data collected shows that climate change and environmental degradations are not the sole drivers of migration.[3] However, they are playing an increasingly large role in aggravating pre-existing vulnerabilities such as the consequences of industrial development, and are already impacting some parts of our world.[4]

It is reasonable to consider international negotiations as the last chance our societies can seize to meet the cost of our (in)action. The global response to climate change is still lacking effective protection for migrants who are uprooted by disasters or slow-onset degradations. No international legal status was created or adapted to allow people to move safely from one place to another. Nevertheless, climate change impacts have started to be addressed in migration frameworks.[5] Migration issues were debated and negotiated during international processes relating to climate change.[6] Some operational links have been developed through institutional cooperation and experience sharing. This coordination is gaining relevance as societies are already experiencing the climate change-migration nexus and are trying to cope. While human rights enforcement has become the main tool for corrective justice,[7] research on distributive justice, which aims to achieve just and equitable outcomes, includes debates on economic and non-economic losses suffered

by environmental migrants[8] and societies. This is a very sensitive topic to address, first because huge political discrepancies can be found within countries on the subject of migration and climate change. Second, at the international level, it is difficult to recognize industrialized countries' legal responsibilities and legal obligations. However, the Cancún framework[9] acknowledged the climate change-migration nexus and considered migration as a way to adapt. Furthermore, international negotiations have strengthened the role of UNFCCC in helping developing economies regarding the issue. In this respect, financial or capacity-building projects, among other actions, have now been launched to improve resilience and protect vulnerable communities.

The Warsaw International Mechanism for Loss and Damage Associated with Climate Change Impacts (WIM) developed in 2013 (COP-19) is a very relevant vehicle that was created to address impacts on societies. Institutionalized by the Paris Agreement,[10] this modest progression could be a real tool for distributive justice. Even if loss and damage is a very controversial issue, some Nationally Determined Contributions[11] have made reference to it. Following this idea, the Task Force on displacement,[12] created by the WIM executive committee, should address controversies regarding changes in responsibility, as a pre-legal context for upgrading protection. Standards included to evaluate economics and non-economics loss and damage regarding migration must be debated, negotiated and adopted.

Measures that could be relevant for addressing the climate change-migration nexus could integrate financial compensation to those who were forced to move, among other things. Different frameworks have been envisaged by authors. Benoit Mayer[13] for example distinguishes three ways of understanding climate change-migration loss and damage capacities: 1) Migration can reduce loss and damage (by moving before the disaster happens), 2) Migration can be a source of loss and damage for migrants (loss of property, loss of rights, loss of protection), and 3) Migration can be a source of loss and damage for the host communities. Accordingly, another aspect could be added: 4) Migration is a source of loss and damage for the communities impacted by climate change and environmental degradations. When a particular society with its own culture, its own history and its own identity loses members, it is a failure for the whole community, which has failed to keep each person safe and secure by protecting their fundamental rights. According to an array of decisions, from UN institutions to national courts, fundamental rights are already jeopardized. The UN Human Rights Committee has advised the international community to go deeper into mitigation and adaptation;[14] otherwise the right to life could be seriously hampered. Two years later, the same UN Human Rights Committee clearly condemned Australia for its failure to implement adaptation and mitigation measures: "(...) the risk of impairment of those rights, owing to alleged serious adverse impacts that have already occurred and are ongoing, is more than a theoretical possibility."[15] To fulfil human rights obligations, States must take sufficient measures and develop their cooperation based on solidarity.[16] In this sense, Christel Cournil and her research team on climate justice have worked on human rights complaints lodged with national courts or UN surveillance committees.[17] Their work on "climate proceedings" is relevant to understand the gaps in international law, due to the political factors arising from controversial issues such as migrations. It is unacceptable to leave national judges alone to face an increasing number of calls for protection. If political institutions continue to deny economic and non-economic loss and damages in the context of migrations, national judges will have to condemn States' inaction and thus be the last barrier of protection, even though the first purpose of States is to respect, fulfil, and give entire effect to international Human Rights law.

That's why the Task Force on Displacement is the ideal solution for moving ahead. From its previous fundamental work on assessing evidence and enhancing cooperation in order to implement integrated approaches, it could be a relevant and insightful way of going deeper and improving the protection of communities already suffering from climate change impacts. It could allow stakeholders to participate in deliberations on which standards could be reasonable and thus gain a greater consensus. By developing standards for evaluating losses at the international level based on rights and needs, it could help achieve global compact incentives and would give realistic content to the commitment made to address the challenges of disasters and climate change impacts on migration, displacement, and mobility. Also, it could contribute to the necessary change from the paradigm of prevention-adaptation to the paradigm of preparation, as advised by a growing social and legal literature.[18] Perhaps, the idea of a responsibility to prepare[19] for climate change disasters should guide discussions and negotiations in developing standards for evaluating disaster and climate change impacts on migration and subsequent loss and damages for both the host and sending communities and for the primary victims: human beings.

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Gender Inequality in the Face of the Climate Crisis

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When we discuss climate change, the topic is frequently centered around its effect on the natural environment. Climate is a multi-disciplinary topic that spans intersections over political, social, economic, and environmental segways. Very rarely do we link this crisis to the nexus between the changing climate and the social environment—specifically in regard to gender. In a world constantly battling the lack of women's rights, this climate crisis only exacerbates the modern-day drivers of social inequalities by placing stress on already tense environments. This stress is even more evident in low-income communities and developing countries where the roles of gender are heavily implemented in tradition. Throughout history, women have stood at the forefront of environmental interactions, and yet, today, they face the biggest implications of environmental degradation. They have less access to depleting food and resource security, a greater displacement due to natural disasters, and a greater risk for sex and gender-related violent crimes. In a world facing a social crisis inside of an environmental crisis, we must ask ourselves how to parallel our fight to mitigate climate change with the threat that gender inequality poses on the safety of women and girls around the world.

Displacement

Four years ago, the US Global Change Research Program released the Fourth National Climate assessment. Four years ago, it was acknowledged that: "Climate change is altering the characteristics of many extreme weather and climate-related events. Some extreme events have already become more frequent, intense, widespread, or of longer duration, and many are expected to continue to increase or worsen, presenting substantial challenges for built, agricultural, and natural systems." (USGCRP, 2018). This is not new information, and nations around the world will have to develop solutions quickly if they hope to be able to cope with the growing fallout of these catastrophic events in coming years. For women, this means growing hardship and increased risk. Globally, women are often given roles as caretakers and providers of resources for their communities, which leaves them more susceptible to the damages of climate change displacement because their livelihood is bound so closely to the conditions of their local environment.

It is important to note that the term "climate refugee" is not yet recognized by the UNHCR (UNHCR, 2022), which means that people displaced or affected by climate change are not always granted the same aid and legal protection that other refugees may be. While it is possible for

people in this situation to be granted refugee status (UNHCR, 2022), there does not yet exist a term which is specifically tailored to helping those displaced by climate change. It is likely that many people have slipped through the cracks of the system as a result of this and did not receive help in their time of need. Not using specific, legally binding terms directly endangers people displaced by climate change, 80% of which are women (Halton, 2018), and therefore exacerbates the hardship that women face in the context of climate-related events. By creating terms to help those displaced by climate change, it can solidify an understanding of the disparate effects of climate change on men and women and garner an environment of refuge that saves the lives of all who are impacted.

Food and Resource Security

According to the (FAO 2010) 795 million people worldwide are undernourished, and food insecurity persists to be a major concern on the global agenda. In developing countries, the prevalence of gender inequality determines the roles men and women are responsible for, and thus, the resulting impacts of climate change on these differing roles (Cramer et al., 2016). The role of women in these communities is dependent on the allocation and responsibility to secure water, food, and cooking fuel. In environments where access to these resources is negatively impaired, there is an increased physical vulnerability (Pachauri et al., n.d.).

Globally, women contribute to 43% of agriculture and food production, and more than 90% of these women are located in African countries (Ziervogel & Ericksen, 2010). Traditional food sources are becoming increasingly scarce and unpredictable. The unreliability of these resource securities and the increased prospect of crop failure will inhibit the income and health of women, as well as create a market of nourishment that is inaccessible in these marginalized communities.

Food security not only impacts food availability, but it also has a detrimental effect on the education of women, specifically girls. Evidence demonstrates that gender inequality, under the effects of climate change, threatens the future of child education, creating precedence of assumed-female roles in the family over the ability to go to school. Girls are often removed from school to help their mothers in the home, especially when the scarcity of food and water rises (UN Women Watch, n.d.). These girls rarely have a chance to continue their education, creating a greater disparity between genders.

Gender-Based Violence

As described in the CARES 2020 Report, the presence of climate change only deepens the driving tension between arbitrary, gender-based inequalities, exasperating the vulnerability and disrespect of women and girls. These increased vulnerabilities include gender-related violent crime, domestic abuse, sexual violence and harassment, underaged marriages, and human trafficking (UN Women, 2022). It is important to note that all genders face sex and gender-based violence (SGBV), but women and girls still face the greatest amount of violence (Desai and Mandal, 2021).

Examples of these SGBV events are littered over communities and history. In the United States, many women were displaced to trailer parks after Hurricane Katrina. During this time, rape cases were 53.6 times higher than they were before (Bachelet, 2022). In Japan, disaster refugees and volunteers of the 1997 and 2010 earthquakes faced a greater chance of sexual assault and rape due to exposure. In Nepal, human trafficking evidently increased after the 2015 earthquake (Desai and Mandal, 2021). In Uganda and Karamoja, there is an increased influx of domestic violence and rape cases during and after droughts (Masson, Lim, Budimir, Podbok, 2016). In areas like Micronesia, limited access to water causes women to walk farther, increasing their vulnerability and risk of rape and sexual assault. In Myanmar, domestic violence increased by 30% following Cyclone Nargis (The Asia Foundation, 2022). In many developing communities where climate induces a lack of sufficient food security, underaged girls are often condemned to early marriages (Desai and Mandal, 2021).

This is only the tip of the iceberg, and yet, there is no justice or mitigation measures in place to combat this rise in gender-based violence against women and girls. The climate crisis is so overwhelmingly discussed, but its indirect nexus to the increase in women who are sexually assaulted, abused, violated, raped, and killed is not. As termed by the UN Women, this is the "shadow pandemic". We are in a worldwide pandemic fueled by a web of overlapping crises. We are all fighting for our survival on this planet, but, in this fight, "women's bodies have become the battleground" (Desai and Mandal, 2021).

Conclusion

Gender inequality remains to be a modern-day crisis, and its prevalence evidently spikes in climate-related events and stress. Even in the face of gender-discrimination, displacement, lack of food security, and gender-related violence, women all over the world are still working to protect their planet and fight against climate change. Women are not just victims of gender discrimination and inequality; they are not just victims of climate change; women are powerful advocates of the natural world, and they can play a crucial role in fighting for the planet. Indigenous women in particular frequently lived in a harmonious symbiosis with their environment. Through intimate familiarity, they take the initiative in defending, conserving, adapting, and safeguarding the natural world and its resources, even in the face of gender inequality.

In the Paramo, located in the Ecuadorian Andes, a group of 86 women have developed a committee to combat the years of degradation and overgrazing in the ecosystem they call home. Although the men have abandoned the land, the women have worked together to develop successful means of sustainable agriculture and landscape management which has led to the revival of the Paramo and its biodiversity (UN Women, 2021). In the 1970s a group of female villagers led a logging strike in the Alaknanda Valley where they stood in place and refused to move from the forest. Not only did these brave women halt the deforestation of their land, they also facilitated a 10-year ban on commercial logging in the area (Mitra, 1993).

Women's environmental expertise and traditional ecological knowledge have always been underappreciated, yet it has the potential to have a significant impact on the progression of climate change research. Despite these invaluable contributions to local, national, and the global economies, women in many countries are excluded from important government or community decision-making sessions. Women deserve equitable participation in the decision-making processes. They deserve to have a say in the processes of laws and regulations at community, state, and federal levels. Their knowledge and experiences are critical resources which will undoubtedly be helpful contributions to the discussion as we attempt to save our species from the impending climate crisis. Climate does not see gender, but we can see the effects of climate change. If we do not put aside our arbitrary social divisions and find a symbiosis among ourselves, inequality will finally cease to exist because we will cease to exist.

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Towards less chemical inputs in agriculture

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Agriculture is undoubtedly one of the human activities with the heaviest impact on the environment, because of a variety of reasons ranging from extensive land use to losses of biodiversity caused by pesticides. I will focus here on the situation regarding the use of chemical pesticides (see review in Jacquet et al. 2022) whose production and use rely on petrochemistry. Despite their serious negative impacts on the environment and health, and despite public actions to reduce their use in many countries worldwide, these chemical inputs have not displayed any significant decrease of use over the last twenty years (e.g. Eurostat data).

Most food systems are currently locked in an unsustainable equilibrium in which the primary production sectors rely upon chemical inputs. The reason behind this situation is that each part of the agricultural sector, from farms to retail, relies on the use of pesticides (Wilson and Tisdell 2001). After World War II, the objective of increasing agricultural production led to intensification of agriculture. This intensification, enabled by high-yielding varieties, chemical pesticides, chemical fertilizers, and mechanization, has been associated with an increase in farm size, to the detriment of biodiversity (Ricciardi et al. 2021), and pest control services provided by ecosystems (van der Sluijs 2020). The dependence of these systems on chemical inputs has thus progressively increased (Meehan et al. 2011). In addition, upstream and downstream sectors have been organized to facilitate and benefit from the intensification of agriculture, leading to a technological lock-in around pesticide use (Wilson and Tisdell 2001). Among all factors involved in this lock-in, the lack of created added value is likely the one that limits implementation of pesticide-free practices the most. Since the products from these practices are not sold at higher prices than conventional ones, farmers have no incentive to implement them. In specific sectors (e.g., fruits and vegetables), implementing pesticide-free practices can also be compromised by market demands for undamaged products (Skevas and Lansink 2014). Undoubtedly, the market does not consider the impact of pesticides on the environment and health (Becker 2017).

Currently, two main consistent strategies for reducing pesticide use exist: integrated pest management (IPM) and organic agriculture. On the one side, IPM is defined by the European Union as the combination of "all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms" and "encourage natural pest control mechanisms" (European Commission 2017). The EU has supported the research and implementation of IPM through National Action Plans (European Commission

2020), based on the idea that pesticide use can be substantially reduced by developing IPM on a large scale (Lamichhane et al. 2015). However, this strategy has not been effective since pesticide use has not decreased (FAOSTAT 2020). Several factors can explain this low impact. First, there is a lack of added value for the sectors that implement IPM, which does not increase the value of products for farmers. Second, there is a wide range of IPM-based practices and farmers often adopt only parts of the spectrum of IPM principles (Lefebvre et al. 2015). On the other side, organic agriculture clearly reduces pesticide use, since it prohibits the use of synthetic fertilizers or pesticides, while maintaining soil fertility and closing nutrient cycles (Reganold and Wachter 2016). Organic agriculture represents a growing sector (increase of 74% from 2008 to 2018 in the EU), but it covers only a small percentage of all farmlands (8% in 2018 in the EU) (Eurostat 2020b). However, organic systems tend to have lower yields than conventional systems (Seufert et al. 2012), even though they are offset at the farm scale by the higher prices of certified organic products, lower input use and agro-environmental premiums in some countries. In addition, some technical issues, (e.g., weed management) are not yet fully solved. Depending on the type of crop production, organic systems can also have more variable yields, which increases risks (Smith et al. 2019).

Agricultural research has a major role to play to go beyond this state of the art and foster new agrifood systems using little or no chemical inputs. However, research concerns itself with pesticide dependence: most research programmes are looking for progressive reduction of pesticides and focus mainly on substitution solutions (Vanloqueren and Baret 2009). This trend gives little priority to research that could lead to disruptive agroecological innovations, not only for pesticide-free agriculture but also for reducing pesticide use greatly. It can be likened to a "fixation" effect, which is characterized by the development of common and conservative solutions to address a complex problem that should require breakthrough innovations (Vourc'h et al. 2018). One solution for overcoming this fixation effect is to clearly state that research and innovation need to work within a pesticide-free paradigm right now. This paradigm removes or relaxes a set of implicit constrains that limit creativity and innovation and are inherited from the agrochemical systems set after World War II, in which curative chemical inputs are the cornerstone. Indeed, currently R&D of agroecological methods must adapt to systems designed for pesticides (monoculture, large fields, little use of resistant cultivars, machinery designed to spray pesticides, advise and distribution channels configured for pesticides, etc.). This not only limits innovation possibilities but also decreases the perceived efficiency of other methods that are used in unfavourable conditions, which restricts their adoption and ultimately public and private investment in their development. Moreover, investment in pesticides still competes with investment on agroecological methods, which remains at a level that is insufficient when considering the current challenge of an agroecological transition in agriculture.

To achieve the pesticide-free goal, several strategies must be designed and implemented simultaneously, which require an investment in fundamental and applied research, and research activities mixing disciplines from biological to social sciences. First, regarding agricultural sciences, cropping systems should be redesigned based on agroecological principles to implement radical change from a curative approach (using curative inputs) to a preventive approach (optimizing prophylaxis and pest control services provided by agrosystems and their surroundings). Second, regarding biological control, strategies should be diversified (with a shift to more services related to conservation biocontrol and inoculative strategies aiming at enhancing permanent or transient pest control) and tailored to a variety of environments and practices. Third, regarding genetics, breeding programs should involve concepts of functional biodiversity and evolutionary ecology. Fourth, regarding machinery, agricultural equipment should be modified to facilitate the transition to pesticide-free agricultural practices, while digital technologies should help optimize pest control and improve epidemiological surveillance. Fifth, regarding economic and social sciences, public policies and private initiatives for the transition toward pesticide-free systems should be implemented.

To achieve this goal, the organisation of research and innovation activities should also be adapted. Previous technical innovations emerged and spread mainly through top-down dynamics: researchers produced knowledge that was transferred to development organizations, which adapted it into applicable techniques and then disseminated it to farms as widely as possible. In contrast, the pesticide-free objective cannot be limited to top-down approaches, but should also value the expert knowledge and know-how of stakeholders in their own geographic area and value chain. This bottom-up approach therefore aligns with the conceptual framework of AKIS (i.e., Agricultural Knowledge and Innovation Systems), which calls for stakeholders along the entire agricultural value chain to interact in order to manage knowledge and develop innovations among them (Knierim et al. 2015). These knowledge flows and innovation-design processes can be managed and supported through participatory research and cooperation organizations, such as living labs, which represent promising tools to enhance open innovations (Kok et al. 2019). This approach is particularly important because many of the solutions that will be developed will not be generalizable everywhere and will require situation-specific innovation. Thus, they must be designed as closely as possible to target situations by considering the resources available and the objectives of the stakeholders concerned, and by closely relating agricultural production and consumption, to engage entire value chains in the design of these transformations (Meynard et al. 2017).

This change of paradigm is supported by several groups of academic players, such as the European alliance "Towards a chemical pesticide free agriculture" (https://www.era-pesticidefree.eu/) and a recently born international initiative on Agroecological Crop Protection. Such initiatives should contribute to produce scientifically sound evidence that pesticide-free systems are possible and sustainable (economically, environmentally, and socially) and that agroecology-oriented value chains benefit from research and innovation activities following this paradigm, and vice versa.

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