SUMMARY

INTRODUCTION

About thirteen years ago, at the beginning of the hopeful 21st Century, the world of science greeted the birth of a new field of study. Barely born, but already bearing a heavy burden, Sustainability Science seemed to embody the expectations and needs of a changing world.

Robert W. Kates, William C. Clark, and the others pathfinder of this new (trans-), wrote in 2001: <<*A new field of sustainability science is emerging that seeks to understand the fundamental character of interactions between nature and society. Such an understanding must encompass the interaction of global processes with the ecological and social characteristics of particular places and sectors (…) [and] integrate the effects of key processes across the full range of scales from local to global*>>.

This statement summarizes the aims and core characteristics of Sustainability Science: not a true mature discipline, nor a research practice, nor a mere point of view.

Sustainability Science is more a transdisciplinary approach, a problem/solution field of study, an holistic method which tries to give effective answers to real questions from a local to a global scale, focusing on every single step between them, and reconciling the gaps.

Agreeing with Laszlo (2001, 2006), Naveh (2007) states that we are experiencing a ''Macro-shift'' which is marked by a severe ecological, cultural, and socio-economic crisis. Thus human society has little time left for the choice of navigating this transformation either to a breakdown or to a breakthrough towards sustainable world. Such a breakthrough is a ''chaos point'' which <<*can be achieved only by an urgently needed, ecological, socio-economic and cultural and technological ''**sustainability revolution**'', leading to the sustainable future of nature and human life on Earth*.>>

As the world hastens one second after another even Science itself must upgrade to move with the times and continuing to serve as a bridge between humanity and the rest of the entire Universe.

1

SUSTAINABILITY:

A NECESSARY PILLAR FOR PRESENT AND FUTURE GENERATIONS

Up ahead in this work we'll discuss the core questions and challenges of the newborn Sustainability Science. But now it is worthwhile spending a few words on the world panorama of the last decades, trying to understand why there's such a big call for sustainability from every single part of the Planet.

After the World War II people in the western countries (mostly) seemed to start breathing a new air, full of promises of well being and freedom. In less than 20 years after the end of the war, the most part of the countries involved had already begun a life of unprecedented comfort. Evidence of this great change is shown analyzing the growth rates: between 1950 and 1970 Italian economy grew with a rate of 5-6%, Germany reached the 8% rate in the first 10 years and even Japan had an unpredictable economic growth with a 9-11% rate. In these years foundations were laid to the today's mass consumption. Van der Leeuw et al (2011) summarize the reach of these phenomena:

<<*Post-WWII, the worldwide popularity of western cultural values has produced trends towards the material-intensive, heavily carnivorous, and energy gluttonous lifestyle wherever it has reached. The national governments (…) have ceded their political economic supremacy to multinational corporations and financial institutions. Tragically, the governance priorities of these new leaders hold wealth accumulation above all else.* >> According to these authors these pro-growth economic policies have contributed to the planet's ecosystems degradation and have a great responsibility in global climate change.

This prevailing paradigm reflected itself not only in decision-making processes but also in society. As Weinstein et al (2013) report: one of the main sources which gave birth to the widespread idea of mankind allowed to exploit and destroy the environmental heritage, lies back in 1944 when the future of world economy and finance was decided in Bretton Woods Conference. In their work the authors point out the evidence of the great misunderstanding (and consequent illusion) that led to the actual global natural disaster, that lies in the words of Henry Morgenthau, Secretary of the Treasury of the United States, which defined the earth as <<*infinitely blessed with natural riches*>>.

Thus, there's no wonder about the careless use of nature that seems to guide the action of people, from decision makers to most of the citizens of the world.

Is there any chance to undermine this paradigm?

What is the role of science in this scenario?

Next to the economic aspects, noteworthy is the incredible progress of science and technology in the last century, and particularly in the last decades. But can progress itself be a solution? Can this "anthropo-systems" find alone their homeostasis? According to Kates et al (2001) the world is actually put at risk by unintended consequences of scientific progress, and therefore there's quite a desperate need of participatory procedures which involve both citizens and scientists.

In addition to that we have to face the fact that nowadays the percentage of urban population of the world has surpassed the rural one[1] (see Fig.1 map next page), thus it is evident that every action undertaken must deal with the new layout and complexity of urban society and its basic needs. Not to forget that urban areas are clearly the most anthropized part of the world, resulting to be the more vulnerable to potential risk due to climate change [(Han J et al (2012)]. Evidences of this statement can be found in the recent event that overturned many parts of the world, striking definitely more the urban areas than the rural ones (north-american hurricanes in the last few years, devastating floods in Europe, f.e.).

In-depth analysis of this phenomena is left for the following chapters, but one last consideration needs now to be made, about the core concept of this entire work: sustainability.

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[1] **World Urbanization Prospects, the 2011 Revision** (2012) *United Nations Department of Economics and Social Affair* http://esa.un.org/unup/

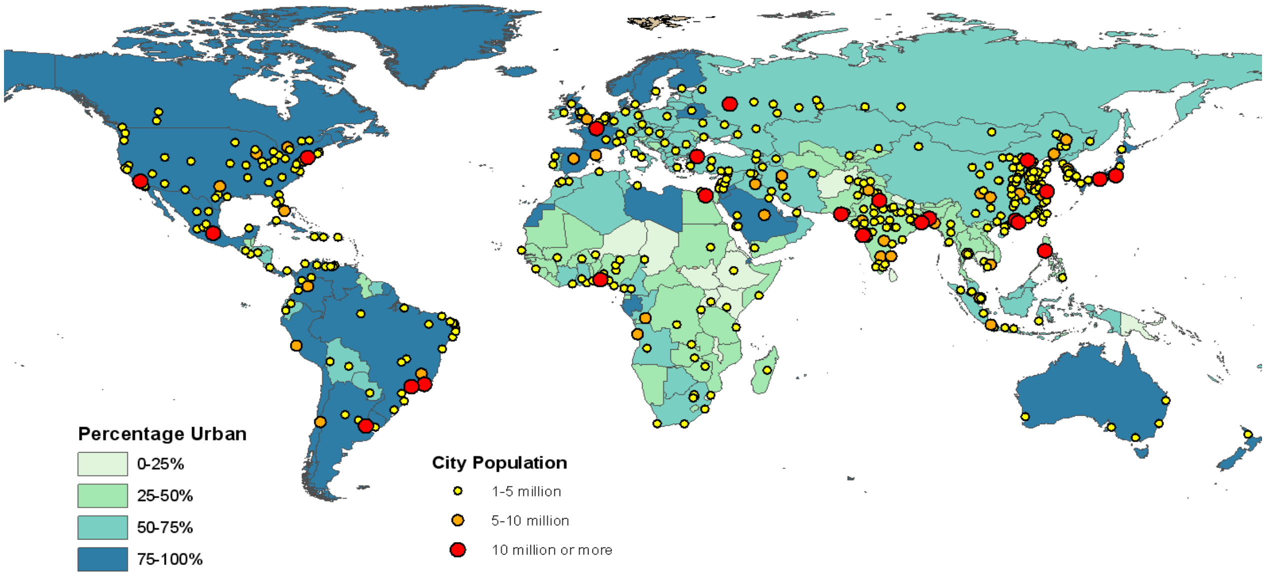

Fig. 1 Percentage of urban population and agglomerations by size class, 2011 **Source**: United Nations, Department of Economic and Social Affairs, Population Division: *World Urbanization Prospects, the 2011 Revision*. New York 2012

As Brandt et al (2013) remember to us, all these multilevel challenges which social-ecological systems are experiencing today (over exploitation of natural resources, social inequalities, climate change etc…), are nothing but interconnected challenges which threaten the sustainable development of society.

So what does exactly mean the word sustainability? And what do we mean when we talk about sustainable development? Plenty of authors discussed the utility and effectiveness of the widespread definition created by the World Commission on Environment and Development (WCED) in 1987: <<*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*>>.

Here we won't enter this discussion but focus on one aspect of the definition. As Spangeberg (2002) stated: <<*Sustainable development is not a positive but a normative concept (…) [which] demands intergenerational justice to preserve the freedom of choice for future generations*>>.

Looking at the present situation, with worldwide natural disasters, economic and political crisis, that goal seems really not so near.

2

SUSTAINABILITY SCIENCE

2.1 Origins and evolution

<<First, the bad news: our civilization is unsustainable and it's getting worse fast>>.

Sterman J (2012)

In this panorama it seems necessary and desirable the creation of a new concept of scientific research, being aware that, using again **Van der Leeuw et al** (2012) words: <<*Painkillers will no more cure a broken arm, than empty rhetoric will cure climate change*>> (statement which can be extended to crisis in many sectors).

> *<<Painkillers will no more cure a broken arm, than empty rhetoric will cure climate change>>*
>
> *Van der Leeuw et al (2012)*

Sustainability Science could fit these needs.

One of the first and best known evidences of its presence in the academic world is the already quoted article by **Kates et al** appeared on Science 292 in 2001. It gave voice to a group of scientists which felt the necessity of taking active part in solving the emerging sustainability problems at many level, by reconciling the scientific world with society:

<<(...) *the challenge of sustainable development is the reconciliation of society's development goals with the planet's environmental limits over the long term. In seeking to help meet this sustainability challenge, the multiple movements to harness science and technology for sustainability focus on the dynamic interactions between nature and society, with equal attention to how social change shapes the environment and how environmental change shapes society*.>> These movements, write **Clark et al** (2003), base their action on the holistic vision, which looks at the whole of the nature-society systems rather than their components. They are problem-driven and well aware that no knowledge can be truly useful unless it is "coproduced" through close collaborations between actors in the academic world.

After a few years, rumors about this newborn peculiar science became greater, even if it still couldn't take the place which deserves in the academic world. **Martens** (2006) still defines Sustainability Science as a scientific sub-current, while highlighting its connection with mode-2 research and post-normal science (more ahead in this work).

One year after, **Ostrom et al** (2007) point out again the importance of a systemic vision to be used in the analysis of social-ecological systems, although warning that <<*If sustainability science is to grow into a mature applied science, we must use the scientific knowledge acquired in the separate disciplines of anthropology, biology, ecology, economics, environmental sciences, geography, history, law, political science, psychology, and sociology to build diagnostic and analytical capabilities.*>>

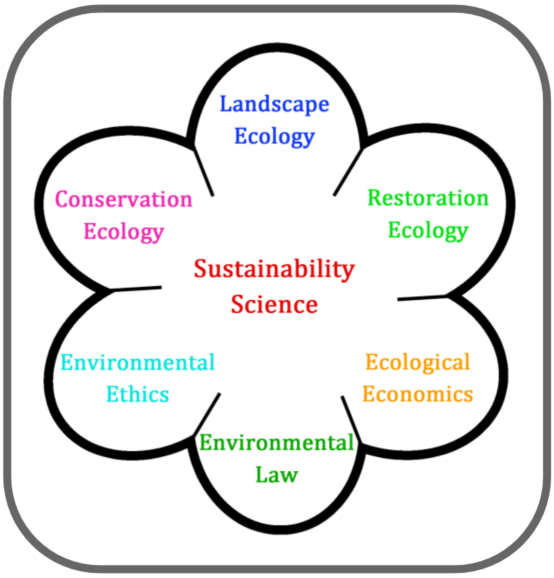

Fig. 2 The flower of sustainability science
Redrawn from Aronson 2011

With **William C. Clark**'s editorial of the February 6th, 2007 issue of PNAS we have another contribution to the shaping of Sustainability Science. Co-author of the first "crying" of this academic newborn [Kates et al (2001)], Clark gives us another hint to draw its blurry profile: <<*sustainability science is a field defined by the problems it addresses rather than by the disciplines it employs.*>> And here it is the evidence of one of the main characteristics of sustainability science: to be a problem- and solution- oriented field. (See also ref. 13)

Moving over through our review, noteworthy is the 2009 work by independent scholar, and like Kates and Clark an S.S.[2] pathfinder, **Jill Jäger**, who, in her background paper "Sustainability Science in Europe" presents the state of the art concerning this brand new field of study. In her concluding remarks she writes: <<*While S.S. may not find the 'final' solution to persistent problems of unsustainability, it will certainly contribute to their mitigation or to reducing their worst impacts by proposing a new way to frame and approach them – more*

[2] From here on, abbreviation for Sustainability Science.

integrative, holistic and place-based – focused on structuring and opening decision-making.>> A certain help to deeper our knowledge of the subject.

After one year **Kastenhofer** et al. make an interesting inquiry: they want to know, analyzing scientific papers stemming from three existing inter-disciplines (ecological economics, technology assessment and science and technology studies), whether there is already one among them with the characteristic of a sustainability science (they indeed speak s. sciences). Without diving to deep into this research, enough to know that the result is no, or at least not completely. So it becomes clearer the innovative character incidental to S.S.. Changing point of view, let's go straight to 2011. Although acknowledging the reductionist risk of setting language boundaries in such complicate fields of study, **Aronson** admits that to enhance the cooperation among scientists it is necessary for them to develop and agree upon definitions. Therefore he offers a way to describe some aspects of Sustainability Science, giving it the shape of a monocotyledonous flower (see Fig. 2). The three upper petals represent as many disciplines whose academic walls shall dissolve to strengthen the emerging S.S.. The lower petals represent three synergistic areas in society, the ones that need to get a first-rank role in it, if sustainability must be achieved. But this goal can only be reached if all the six petals start thinking to themselves as parts of the same flower.[3]

Fig.3 [Fig S1 in Bettencourt & Kaur (2011)] **Word cloud showing the relative frequency of most frequent words in publication titles.**

In the second decade of the XXI^st Century there are still authors wondering whether sustainability science has actually become a field of science, though recognizing its pioneering character. Interesting the work by **Bettencourt and Kaur** (2011), two "outsiders" of S.S. [according to **Kates** (2011)] who state indeed that there's no other example in the history of science <<*of a field that could span such distinct dimensions and achieve at once ambitious and*

[3] Aronson J (2011**) Sustainability Science demands that we define our terms across diverse disciplines.** *Landscape Ecology* 26, 457-460

urgent goals of transdisciplinary scientific rigor and tangible socioeconomic impact.>> Fortunately the same authors come to a positive conclusion: Sustainability Science can actually be referred to as a proper field of study, although with unusual characteristics. The answer comes as a result of the research made analyzing temporary evolution of scholarly publications about S.S. via keyword searches over the period of 1974–2010. Figurative example of the results is shown in Fig. 3 (Fig. S1 in the above mentioned work).

Finally let's take a look at the literature published in the last few years.

After more than ten years since the appearance of Sustainability Science on academic shelves it seems to be time to take stock of the work done heretofore.

Wiek et al (2012) publish a "comparative appraisal of sustainability science projects" where they <<address the theory of sustainability science from an empirically informed bottom-up perspective>>. Confronting theory with empirical projects they try to understand whether there's a true contribution to the solution of the problems, or it all remains a mere comprehension of them. They pose a very important question: is sustainability science really able to solve such critical situations?

The second last article presented in this review has behind itself most of the authors we met in the previous works. But here **Lang, Wiek et al** (2012) instead of focusing on what S.S. is or should be, prefer to develop the subject from a more practical side, namely discussing its "transdisciplinary heart".

Last but not least in 2013 another article undertakes the sustainability science question from various point of view. **Weinstein et al** first show the disastrous environmental effect of the Anthropocene (Ref. Annex 1) making the almost fearful statement that <<we seem to be moving along a path where innovation is primarily leading to optimization of the status quo rather than to system innovation.>> Then they present possible ways to enhance the transition to a sustainable world, interlacing six major challenges to <<the nascent field of sustainability science>>.

At the end of this overview we have a vision of something beautiful and hopeful, but it feels like there still is a lack in practice. Sustainability science is shaped by now, but how can it begin to discharge its duties?

2.2 Foundations: Post-Normal Science, Mode-2 process and Transdisciplinarity

As Funtowicz and Ravetz already stated in 1993, Science always evolves in line with the times and their challenges. The complexity of the problems that humanity and, in a broader vision, the entire Planet, are facing now, is so high that the traditional disciplinary and research methods look obsolete by now, and a new approach to address these challenges is needed. [Lang et al (2011), Van der Leeuw et al (2011), Brandt et al (2013), Weinstein et al (2013)].

First of all in front of all these tight interactions a single-discipline approach seems completely useless, but what are the alternatives? Gibbons et al (1994) proposed a shift from Mode-1 research method (academic, monodisciplinary, technocratic) to Mode-2. This new concept of science is based on the involvement of non-academic staff in the research process, the resort of all the disciplines related to the research object, and it's more participative. **Mode-2** method goes along with the concept of **Post-Normal Science**, created first by Funtowicz and Ravetz (1993). The authors have a clear vision of the world scenario in the last decades of the XXth Century and therefore they hope for an upgrade of science methods: <<*Whereas science was previously understood as steadily advancing in the certainty of our knowledge and control of the natural world, now science is seen as coping with many uncertainties in policy issues of risk and the environment.*>> They further offer a description of the core elements on which this new scientific method is based: << *This emerging science fosters a new methodology that helps to guide its development. In this,* ***uncertainty*** *is not banished but is managed, and* ***values*** *are not presupposed but are* ***made explicit****. The model for scientific argument is not a formalized deduction but an* ***interactive dialogue****. The paradigmatic science is no longer one in which location (in place and time) and process are irrelevant to explanations. The* ***historical***

> *<<The historical dimension, including reflection on humanity's past and future, is becoming an integral part of a scientific characterization of Nature.>>*
>
> *Funtowicz and Ravetz (1993)*

dimension*, including reflection on humanity's past and future, is becoming an integral part of a scientific characterization of Nature*.>>

Such a revolutionary vision of Science gave rise to a big noise [Nowotny et al (2002)] and clearly needs to be constantly upgraded [Ravetz (2007)], but without entering to deep into science philosophy, enough to say that these new theories gave a determining contribution to the birth of sustainability science, which can doubtless be defined has a Post-Normal Science based on a Mode-2 research approach [Martens (2006)].

One of the core elements that is noteworthy in this analysis of these new scientific paradigms is the involvement of a plurality of disciplines in the research process.

Multidisciplinarity, interdisciplinarity and transdisciplinarity are concepts now familiar to contemporary scientists, nevertheless there is still confusion about the deeper meaning of them, or their boundaries. Kastenhofer et al (2011) for instance, studied the role of <<*newly established inter-discipine*>> which are seen as sustainability science forerunners (human ecology, social ecology, ecological economics, etc…). That conceded, if S.S. is commonly defined as a transdisciplinary science, what is the main aspect which discriminates an interdiscipline from a transdiscipline? Moving on the path outlined by Spangenberg (2011) we can pinpoint three aspects which help us distinguish the different interactions among

diverse disciplines while facing a problem (multi-, inter-, transdisciplinarity) (See fig.4):

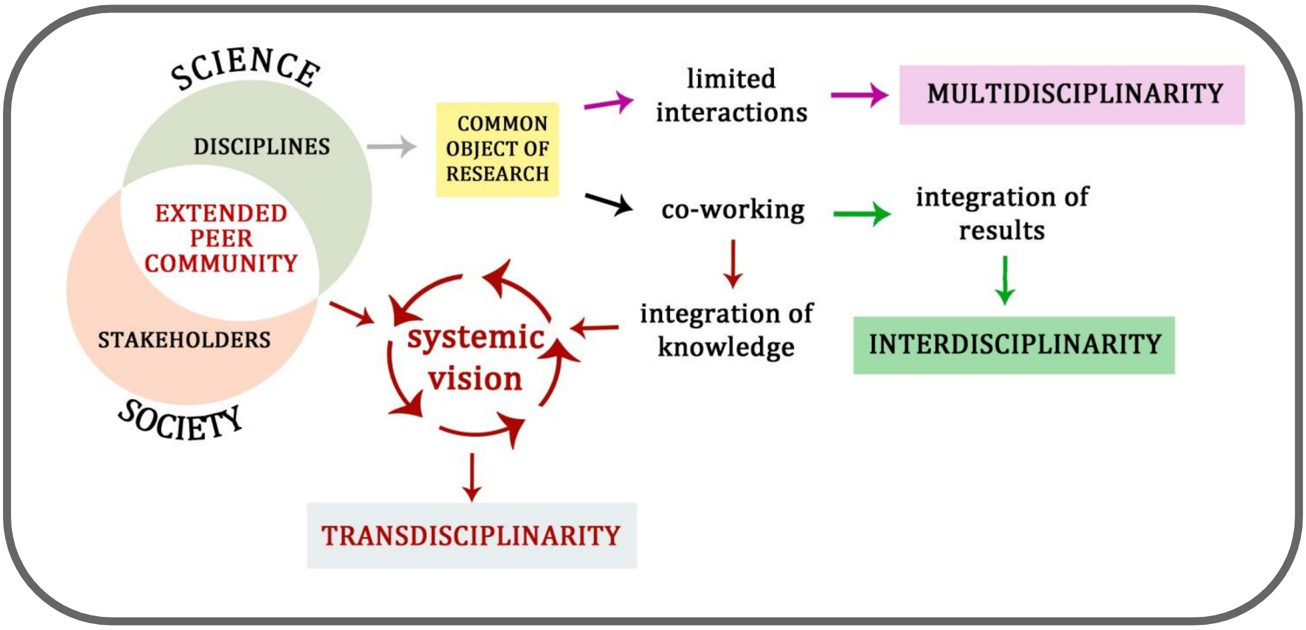

Fig. 4 Different methods to approach a common object of research

Transdisciplinarity is a <<*demanding form of knowledge integration*>> which, transcends from the partial point of view of each single discipline involved, to create a thorough reference frame which defines the problem [i.e. it uses a **systemic approach**, Caporali et al (2010)];

As in an interdisciplinary approach, transdisciplinarity requires the involvement of diverse disciplines also in the research process. But the element of innovation is the necessary contribution from non-scientific knowledge, i.e. non-academic stakeholders: the so-called <<***extended peer communities***>>.

The two groups implied in the research process, namely "science" and "society" are bound by tight relations. Both their contributions are needed to solve such complicate problems.

Brandt et al (2013) give us an in-depth analysis of the difficulties that a newborn science like sustainability science has to face while encompassing a transdisciplinary approach. The first challenge is the lack of coherent framing of the problem, due to the different background of each person involved in the research process (both from science and society). Then there's a problem in the integration of methods to enable useful and efficient learning process between the research process actors. The third challenge concerns the effective research process and the knowledge production, which can be divided in three phases:

- Problem identification and structuring (collaboratively)
- Problem analysis (co-creation of solution-oriented and transferable knowledge)
- Integration and application (implementation of the results into practice)

Another challenge is to engage practitioners, and finally to generate impact.

Transdisciplinarity thus seems to be one of the best methods to face contemporary challenges, nevertheless it is not clear whether its extent is fully acknowledged [Brandt et al (2013)]. A thorough evaluation shall be done only when scientific literature on the subject will be more solid.

3

A CONCRETE HELP TO FACE THE CHALLENGES OF THE XXIST CENTURY

BIG-PICTURE FINDINGS ON GLOBAL CHANGE

Adapted from Steffen et al (2005)

THE EARTH IS A SYSTEM THAT LIFE ITSELF HELPS TO CONTROL

Biology is the key factor which keeps Earth habitable.

GLOBAL CHANGE IS MORE THAN CLIMATE CHANGE

It is real, it is happening now and in many ways it is accelerating.

THE HUMAN ENTERPRISE DRIVES MULTIPLE, INTERACTING EFFECTS THAT CASCADE THROUGH THE EARTH SYSTEM IN COMPLEX WAYS

THE EARTH'S DYNAMICS ARE CHARACTERIZED BY CRITICAL THRESHOLDS AND ABRUPT CHANGES

Human activities could inadvertently trigger changes with catastrophic consequences for the Earth System.

THE EARTH IS CURRENTLY OPERATING IN A NO-ANALOGUE STATE.

Its simultaneous changes are so variable that there are no similar examples perhaps in the history of the Earth.

BOX 1. Adaptation from Steffen et al (2005)

<< It is easy to draw a dramatic picture of today's world. Climate change, the most serious environmental challenge humanity has to face, is threatening the well-being of the next generation. Globalization has led to rapid economic, social and technological changes that have left too many behind. Hunger is still a persistent problem, affecting over 900 million human beings worldwide. Faced with these issues, we sometimes feel overwhelmed by their magnitude and powerless.>> FAO (2013)

Global change: two words which summarize the seriousness and the range of the cross-cutting shifts that are occurring in this very moment at any level of the world-system. The extent of it is summarized in **box 1**, an adaptation from "Global Change and the Earth System: A Planet Under Pressure" by Steffen et al (2005). In this book the authors outline this crucial phenomenon, or this series of interlaced phenomena, promoting the birth of an "Earth System Science" in some ways similar to S.S..

Travelling through the scientific production on the subject it seems every day clearer that the main and strongest cause of this global twisting is without doubt Mankind. [Crutzen PJ (2002), Steffen et al (2005), WBGU (2011)]. Even if change is definitely a constitutive element of life, the question lies in its speed and if, and to what extent, resilience can be a sufficient and effective answer to that, and how it could be enhanced.

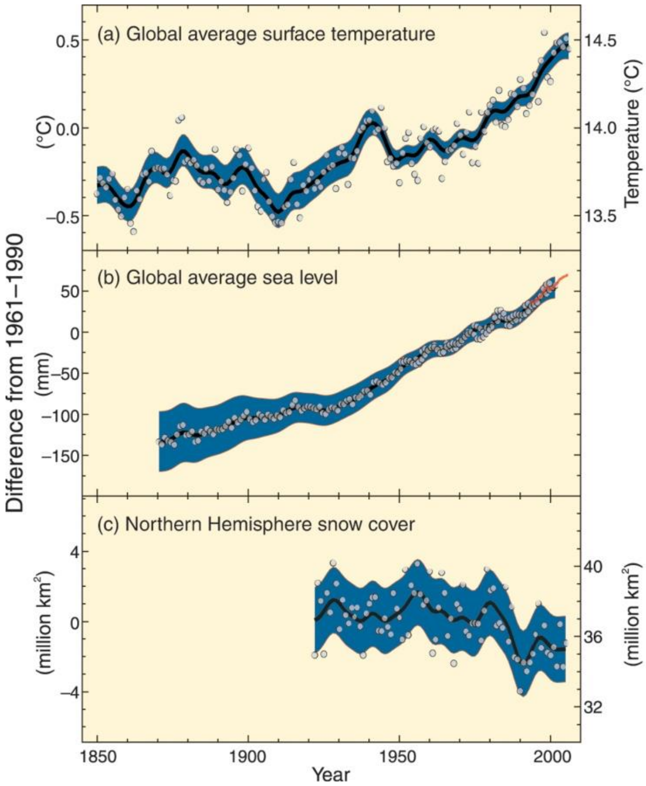

Fig.5 Climate parameters showing global warming.
Source: IPCC IV Assessment Report, 2007

Sustainability science is born to face and understand this change [Kates et al (2011)] tracing a concrete path to the sustainability transition [Weinstein (2012)].

The challenges that this new science is called to tackle are so various and complicated that never such a work could possibly thoroughly deal with them. As reported in one of the founding article about S.S. [Kates et al (2001)] they even extend to a full range of scale from local to global. Therefore it seems useful at least to briefly address some of these challenges to create a clearer stage on which sustainability science is about to act.

3.1 Climate Change

<<*Warming of the climate system is unequivocal, human influence on the climate system is clear, and limiting climate change will require substantial and sustained reductions of greenhouse gas emissions*>>. With this undisputable sentence the **IPCC** opens the press release which presented to the world their Fifth Assessment Report on Climate Change on January, 30 2014[4].

The **Intergovernmental Panel on Climate Change** is the evidence of the first international acknowledgement of Global Warming. Established in 1988 by the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) it is not a research institution, but its duty is to spread the results of scientific studies and research produced worldwide, that are relevant to the understanding of climate change. <<*The role of the IPCC is to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of* ***human-induced*** *climate change, its potential impacts and options for adaptation and mitigation*.>>[5]

Once again the anthropic foot-print on the environment plays a lead role, and the range of it, its consequences, are so heavy that the same IPCC has been rewarded with the Nobel Prize for Peace in 2007. This is one of the greatest proves of the strong interconnection between environment protection and socio-political stability: not only humans have an unprecedented influence on the environment, but the results of their actions on it fall back on the anthropo-sphere. This fact implies another consideration: the measures we take to reduce our impact on the global ecosystems have not the sole goal to preserve them for the future generation, but they are needed also to guarantee and improve the life of the present citizen of the world:

<<*Extensive climate changes may alter and threaten the living conditions of much of mankind. They may induce large-scale migration and lead to greater competition for the earth's resources. Such changes will place particularly heavy burdens on the world's most vulnerable countries. There may be increased danger of violent conflicts and wars, within and*

[4] http://www.ipcc.ch/pdf/press/press_release_wg1_full_report.pdf
[5] Principles governing IPCC work, 1988 http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles.pdf

between states.>> writes the Norwegian Nobel Committee[6]. And here sustainability science appears to be one of the main (trans-)disciplines able to find ways to the solution or at least understanding of such a big challenge.

The IPCC thus outlines the state of art of research on climate change, but then how are the Governments responding to that? As these are major global challenges, the actions against them in turn must be global.

The **United Nations Framework Convention (UNFCCC)** was formed in 1992 as an international treaty to fight climate change and its consequences. In 1997 has been adopted the well-known **Kyoto Protocol** which set internationally binding emission reduction target under the principle of "common but differentiated responsibilities" (developed countries, main responsible for the actual situation, were put stricter limits).

Nevertheless the agreement entered in force not earlier than 2005 and right away showed

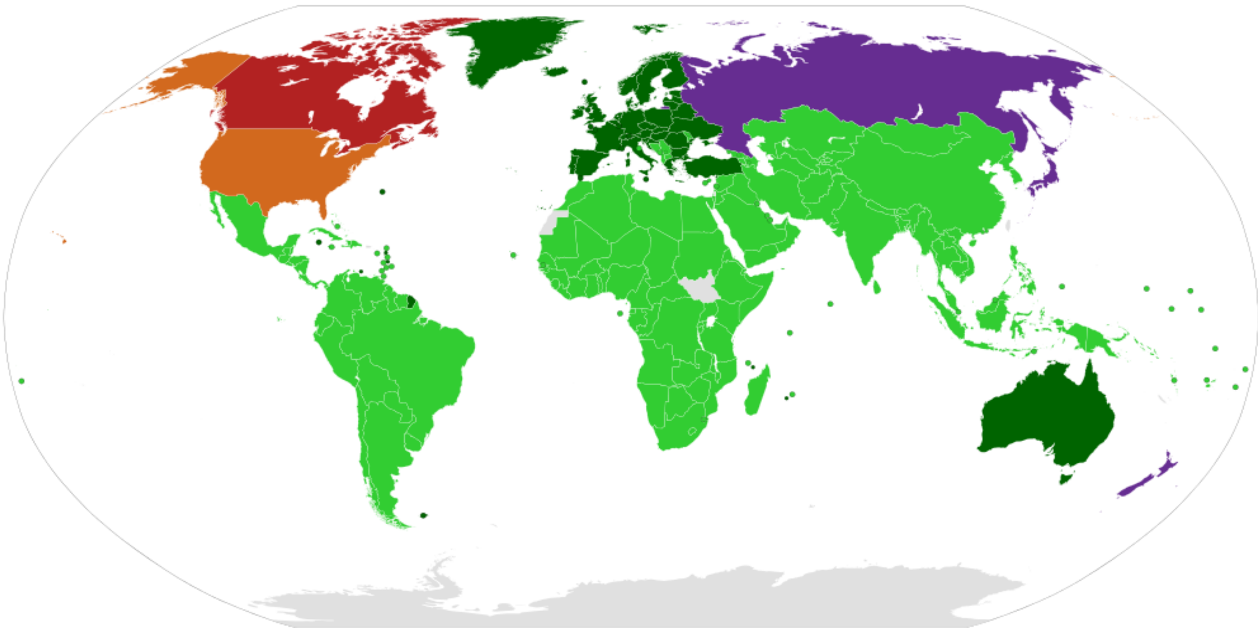

Fig. 6 Kyoto Protocol participation map (commitment period: 2013-2020)

- Parties; Annex I & II countries with binding targets
- Parties; Developing countries without binding targets
- States not Party to the Protocol
- Signatory country with no intention to ratify the treaty, with no binding targets
- Countries that have renounced the Protocol, with no binding targets
- Parties with no binding targets in the second period, which previously had targets

Source: Wikimedia Commons

[6] http://ww

all its weakness: the United States, principal responsible of the totality of greenhouse gasses (GHG) emissions (see Fig. 6) did not ratify the Protocol, then Canada withdrew from it in 2011.

The Protocol was divided in two commitment periods:

I. 2008-2012: reduction of GHG emissions to an average of 5% against 1990 levels;
II. 2013-2020: reduction of GHG emissions by at least 18% against 1990 levels.

In this work we won't dive into the whole of actions taken by single or groups of nations, nor discuss the reservations made by single parties in the Kyoto Protocol, but looking at the most important international union, the U.N., a consideration is needed: are these measures sufficient? Are Nations really aware of the magnitude of this unprecedented challenge? No, from many points of view. Even if we follow the traditional reductionist vision it could be sufficient a glance at the map in figure 6 to answer no. But if we even use the systemic vision, proper of the actual scientific streams, can the reduction of GHG emissions be the solution? Or are there many other key factors which intervene in this core question?

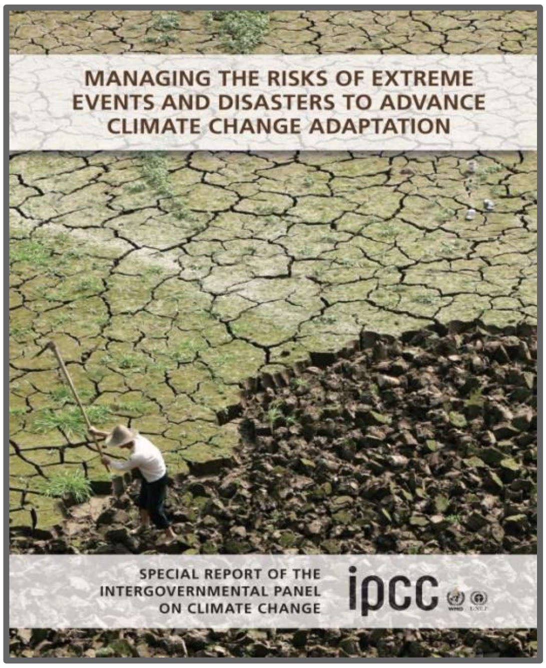

Fig. 7 Front cover of the IPCC 2012 Report

Agreeing with Sterman (2012) even if Sustainability is becoming a mainstream concept, from the high benches of Politics, to the simplest civil actions like recycling, << *the most efforts by firms, individuals and governments in the name of sustainability are directed at symptoms of unsustainability rather than causes* >> and in addition to that there is the increasing suspect << *that the policies we implement to address difficult challenges have not only failed to solve the persistent problems we face, but are in fact causing them*. >> This resulting in the creation, by well-intentioned programs, of side effects and the consequent policy resistance. Sterman (2012) again reports some clarifying examples, like the incautious construction of levees and dams which, in some case, instead of preventing, have led to more severe floods.

Once again is evident the necessity of an holistic vision to understand the tangled net of interconnections between global and local phenomena.

3.2 Biodiversity Loss

As stated since the first chapter of this work, everything in the Universe is deeply connected. And these connections are so deep and complicated that a complete understanding of them is hardly imaginable.

A few lines ago we've been discussing the extent of the Climate Change phenomenon, but it's time to see to what phenomena it is a driver in turn.

Biodiversity is one of the greatest riches on the Planet: it represents the ability of Nature to evolve and improve, and all that is made with an harmony almost unknown to humans. But to restore the balance between its elements, to promote resilience, Nature has its time, which nowadays doesn't coincide at all with Man's.

Climate change is not only an effect, but also a cause to global phenomena that range from extreme disasters [IPCC (2007, 2012); Rahmstorf S, Coumou D (2011)], which are under daily media coverage, to more hidden outcomes. These under-cover effects don't seem to directly affect human well-being, that is why they are often taken more lightly, and there are no media talking about them on a daily base, unless some specific ones. Biodiversity loss is in fact one of the less visible (to a superficial glance) consequences of climate change and the more it is invisible to a human eye, the more it is dangerous, like a viral disease.

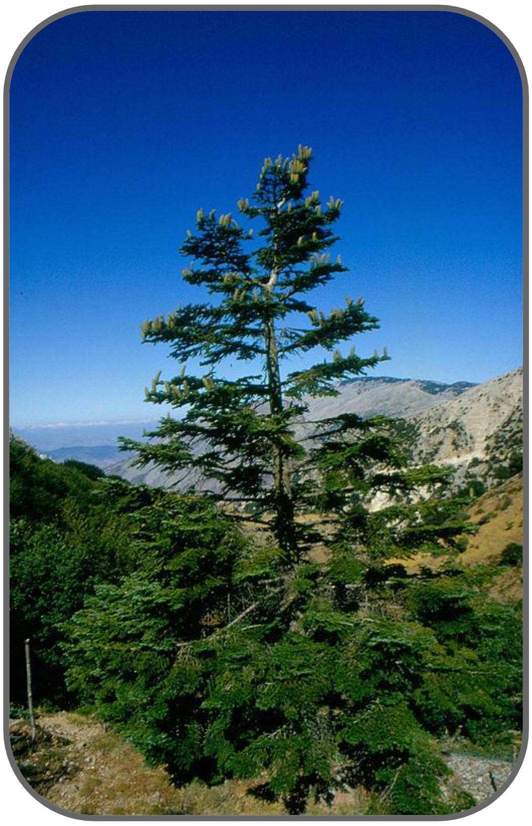

Fig. 8 Abies Nebrodensis, classified as 'critically endangered' in the IUCN Red List

Since 1964 **IUCN** (International Union for Conservation of Nature) publishes the **Red List of Threatened Species**[7], a thorough inventory of the conservation status of the biosphere. The last update in 2012 assessed more than 63.000 species on the list, divided in 9 groups upon degree of conservation, from 'not evaluated' to 'extinct'.

[7] www.iucnredlist.org

To evaluate the trends in biodiversity consistency, Thomas et al. (2004) used projections of species' distributions for future climate scenarios, assessing extinction risks for sample regions that cover about 20% of the Earth's terrestrial surface. Thus, imaging a mid-range climate-warming scenarios for 2050 they predicted that 15–37% of species in the sample of regions and taxa will be **'committed to extinction'.** Other authors even stated that Thomas et al underestimated the problem [Harte et al (2004)]. Not to forget in addition, that the character of an ecosystem is to be formed by tight and complicate relations, therefore the loss of one specie in one area, no matter how big it is can induce a "cascading co-extinction" [Mori et al (2013), see box on page 21].

That conceded, what on its turn implies biodiversity loss? Are we only talking about a few species becoming history, or are there really bigger implications that will in many ways affect our very lives?

According to the Organization for Economic Cooperation and Development [**OECD** (2012)] until 2050 we'll lose another 10% of terrestrial biodiversity (measured as MSA – mean species abundance); the area of mature forests, which are richer in biodiversity, is projected to reduce by 13% and although about one-third of global freshwater biodiversity has already been lost, further loss is projected to 2050. It is noteworthy though, in a world shaped by economy and finance, that this is not a mere ecological task. Biodiversity loss implies the demise of such an amount of ecosystem services which the **TEEB** (The Economics of Ecosystems and Biodiversity) evaluated to be around **USD 2 and 5 trillion per year** (OECD, TEEB).

But without being so mercenary (though in the XXIst Century it is one of the key factor always to consider) biodiversity loss implies deep and fearful consequences worldwide. In their clarifying essay of 2006, Dìaz et al explain how biodiversity loss threatens human well-being. Recognizing what we already stated, i.e. that drivers of biodiversity loss, like climate change for instance, have a more dramatic evidence and direct impact on society, they argue that the degradation of the ecosystem ("tapestry of life" in the text) is also <<*threatening the fulfillment of basic needs and aspiration of humanity as a whole, but especially, and most immediately, those of the* ***most disadvantaged segments of society***>>.

<<In semi-arid woodlands dominated by pinyon pines (Pinus edulis) and one-seed junipers (Juniperus monosperma) in the southwestern USA, severe drought has been observed in recent years, resulting in the high mortality of mature pinyon pines (Mueller et al., 2005). If global warming increases the frequency and severity of droughts, pinyon–juniper woodlands will become dominated by juniper, which is tolerant of more arid conditions. Mature pinyon pines attract birds through their cones for seed dispersal and burial (Chambers, 2001). Furthermore, mature pines have an important role as nurse plants, providing mutualistic ectomycorrhizas for successful pine seedling establishment (Gehring and Whitham, 1994). Given that pinyon pines coevolved with birds (Christensen et al., 1991) and that one-seed junipers mainly support arbuscular mycorrhizas that can result in the reduced ability of pinyon seedlings to re-colonize sites of high pinyon mortality (Haskins and Gehring, 2005), the loss of mature pinyon pines is expected to make the re-establishment of this species difficult even if climate conditions became more favourable. Because approximately 1000 species, from microbes to vertebrates, are associated with pine–juniper woodlands, the problem is not only the potential loss of pine populations (Mueller et al., 2005). This example implies that there is a risk of the cascading 'co-extinction' (sensu Koh et al., 2004) of many species at the local to regional scale when the foundation species (Ellison et al., 2005) is lost.>>

Mori et al (2013)
References in the quote can be found in the original article

In the picture: **Pinyon - juniper woodland on the Serpents trail, near Grand Junction, Colorado**

The failure of international policies in the environmental area is clearly shown also in this case. First by EU Countries, then by many other nations worldwide, 2010 was globally set as deadline to halt biodiversity loss[8] (2010 was thus declared 'International Year of Biodiversity' by the 61st session of the United Nations General Assembly in 2006).

When it became clear that this target could not be achieved, the international **Convention on Biological Diversity** (an international treaty wanted by UNEP and in force since 1993)[9] gathered in October 2010, in Nagoya, Aichi Prefecture, Japan, and adopted a revised and updated **Strategic Plan for Biodiversity**, for the 2011-2020 period. These ten years have been declared "The U.N. Decade of Biodiversity" during which the Parties are committed to reach the twenty '**Aichi Targets**' collected in five greater goals (see Box below).

AICHI BIODIVERSITY TARGETS

-STRATEGIC GOALS-

A- Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society

B- Reduce the direct pressures on biodiversity and promote sustainable use

C- To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity

D- Enhance the benefits to all from biodiversity and ecosystem services

E- Enhance implementation through participatory planning, knowledge management and capacity building

We all hope that these targets will finally be reached, but looking at the past and present situation there still remains great concern about our true acknowledgment of the question. In addition to that concern arises from the arguable decision of some international institutions like the same IUCN. As Beumer and Martens (2013) recall, IUCN in 2007 signed a controversial partnership with Royal Dutch Shell, which a few years later has been officially accused by UNEP to have a role in the natural and social disasters caused by oil pollution in Ogoniland, Nigeria [UNEP (2011)]. The IUCN in 2013 released, under commission from the same Shell Petroleum Company, a report on the sustainable way to remedy the damages at the habitats of oil spill sites in the Niger Delta [IUCN-Niger Delta Panel (2013)].

[8] http://www.countdown2010.net/
[9] http://www.cbd.int/

That said, the concerns expressed by Beumer and Martens (2013) don't seem so pointless when they wonder whether: <<institutions like IUCN can maintain their integrity and can continue pursuing their mission according to their vision if their projects become entangled with the activities of large multinationals [Turner (2010), FOEI (2009)]>>.

Unfortunately such an interesting subject cannot be more addressed in this work, but if we want to start drawing some conclusion it seems to be more and more clear that the solution of such intricate questions cannot come from Institutions or scientific panels alone. It requires a systemic vision, a brand new approach which also includes the stakeholders who are increasingly been kept outside of restoration processes. As the same IUCN reported about the population who suffered from oil pollution in Niger Delta region << One of the critical outcomes of the field investigations was that community stakeholders were eager to be part of remediation activities and felt that it was unacceptable that they were excluded from decisions of such importance that had far reaching impact on their environment and communities.>> [(IUCN-Niger Delta Panel (2013)]

Even if the question is not directly related to biodiversity, it is worth to remember that the same situation occurred in Italy after L'Aquila earthquake in 2009, when citizen were totally left out of the reconstruction process.

3.3 Land Degradation and Fertility Loss

Soil is unequivocally the substratum of life. It is comparable to a real organism in which the relations among its components are so tight and complicated, and so much interconnected with the rest of the ecosystem that a little change in one of them produces a long and deep series of other effects [Doran (2002)]. The importance of these relations, and the heavy footprint of human activity on them, are well shown by Steffen et al (2004) who state that in the world <<*nearly 50% of the land surface has been transformed by direct human action, with significant consequences for biodiversity, nutrient cycling, soil structure, soil biology, and climate*>>. Soil health is intimately dependant on other phenomena we've been discussing before, including climate change and biodiversity loss [WMO (2001), Steffen (2004)].

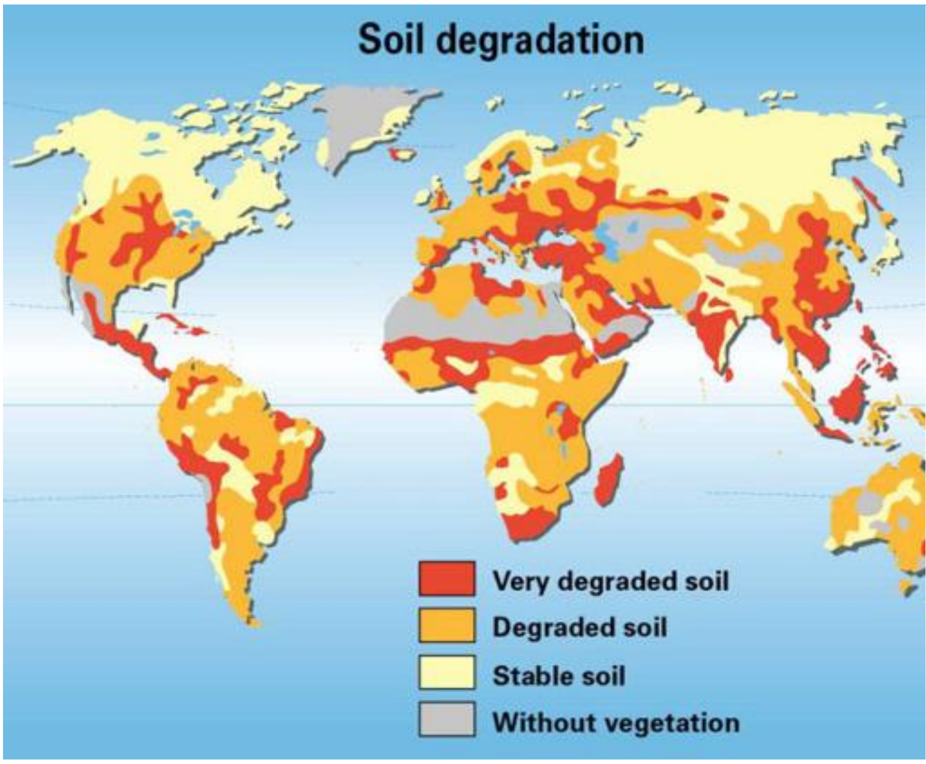

Fig. 9 Global soil degradation

The loss of arable land has been caused by a number of factors, many or most of which are tied to human development.

Originally drawn by Philippe Rekacewicz upon 'Atlas of desertification in the world, Second edition, Arnold Publishers, London, 1997'

Credits: http://www.grida.no/graphicslib/detail/global-soil-degradation_eeea Author: Philippe Rekacewicz, UNEP/GRID-Arendal

Therefore the preservation of one of these components is necessary to the preservation of all the others. The concept of Soil Quality (SQ) has been extensively discussed in the last twenty years, [Dorlan et al (2008)]. Functional to our work is the definition adopted by the European Union [Tòth et al (2007)]: **'Soil Quality is an account of the ability of soil to provide ecosystem and social services through its capacities to perform its functions and respond to external influences'.** The soil quality is thus one of the most important indicators of sustainability and all its constitutive elements can be defined as sustainability indicators. Many factors can affect soil quality, from inner ones (depth, composition, texture, etc…) to environmental ones (climate, biogeochemical processes, etc…). But what generates the biggest impact to soil quality is once again the anthropic footprint [Magdoff & Weil (2004), Steffen (2004)]. Man affects soil in many direct and indirect ways, from agriculture and all the others land use change (urbanization above all) to climate change induced drivers (soil erosion due to abnormal meteorological phenomena, desertification due to warmth increase and soil resources overexploitation) [WMO(2005)].

This results in the definition of soil as **non-renewable resource**: in fact, while the environmental factors which influence soil quality are part of the ecosystem, and thus subdued to resilience processes, the anthropic ones occur with such intensity and speed that there is no possibility for the soil to recover its original status unless, for definition, in geological times: in Guatemala, for instance, there are still soils trying to recovery from the Maya's activity on them [Olson (1981), Karlen (2008)].

One of the SQ indicators whose vital importance is yet universally recognized, not only in Agricultural Sciences, is **Organic Matter** (OM), whose importance is summarized by the definition from Rusco et al (2001) of <<elixir of plant life>>. As Magdoff and Weil (2004) recall, OM is one of the most complex and least understood component of soils. Cultivated soil contain 10 to 40 g/kg OM in the first and most fertile centimeters of ground. OM's importance as soil quality parameter is also evident from the influences it has on many other soil components and functions. Among others it reduces soil erosion, improves the micro-biodiversity and balances pH [Grego et al (2008)]. Unfortunately past years' agriculture, based on extended use of fertilizers, invasive soil management practices, monoculture and other disruptive actions against the agroecosystem, heavily affected the OM contents, and thus the overall Soil Quality [Doran (2002), Karlen (2008)].

That said, what is the actual status of soil in the world? How deep has Man affected soil quality since its first appearance on the Planet? It is very difficult to give a definitive answer to this fundamental question. The first global assessment on land degradation was the GLASOD project (Global Assessment of Human Induced Soil Degradation) which took place between 1987 and 1990. Funded by UNEP, the project produced, on expert opinion basis, a world map of human-induced land degradation, followed by an explanatory note on which it is officially stated that: << *Past and present human intervention in the utilization* *and manipulation of environmental resources are having unanticipated consequences. The often-indiscriminate destruction of forests and woodlands, and the spectre of land degradation resulting in decreased productivity with dire social consequences is generally recognized. The earth's soils are being washed away, rendered sterile or contaminated with toxic chemicals at a rate that cannot be sustained.>>*[10]

The project showed that at that time the 65% of agriculturally used land had signs of degradation (40% strong or very strong), and considering the recent global tendency in agricultural practices which, to increase food supply, have had detrimental impacts on the environment [Tilman (2002)] it's easy to imagine that the percentage will now be greater.

Two decade after, GEF (Global Environment Facility) UNEP and FAO promoted the GLADA - Global Land Degradation Assessment in drylands project that used a sequence of analyses to

[10] There is no other official reference to the GLASOD project that the page about it on the ISRIC website http://www.isric.org/projects/global-assessment-human-induced-soil-degradation-glasod, where a zip file containing the explanatory note can be downloaded.

Fig. 10 An example of transdisciplinary approach in soil management
Created by Author from: Lal R (2010)

identify land degradation hotspots using remotely sensed data and existing datasets. In Bai (2008) are reported some of the conclusions to which the project came. They revealed that the global issue is that **land degradation is cumulative.** Indeed, compared with GLASOD results, which showed that the 15% of land surface was degraded, the GLADA revealed a 24% of land degrading but the areas in the two projects are mainly different. Since land degradation in GLADA is defined as a long-term decline in ecosystem function, and measured in terms of net primary productivity, this means that the most of the land already degraded in 1991 persists in that state, but new areas are now losing their quality.

Looking at the complexity of these phenomena, which usually happen with a cascade of side-effects, and thinking at the ever increasing world population, the task of soil protection seems really hard for Governments to tackle. And that's why again a science with a systemic basis, like Sustainability Science is really desirable for the Planet in the XXIst Century.

<<It is really hard to stay green when you're in the red>>

Anonymous

3.4 'Environomical' crisis

The second decade of the XXIst Century has opened with a global dramatic scenario. The failure of the present economic and financial paradigms [Ayres et al (2013), Peretz (2013), WBGU (2011) has led to a massive crisis which affects most of the developed Countries, adding up to, and sometimes worsening, the difficult situation that the rest of the world was already suffering. It is widely recognized that in economic difficulties the environmental issues are moved to the background [Clapp et al (2009), WBGU (2011)] and as the U.N. recalls in the Rio+20 Resolution on 07.27.2012[11]: <<*Poverty eradication is the greatest global challenge facing the world today and an indispensable requirement for sustainable development* >>. The tight connection between economy and environment is thus formally stated. The aforementioned document is called "The Future We Want", **but is it only a question of *wish*, or rather of *need***?

Even if someone could see the present crisis as nothing but a repetition of a recurrent historical event which eventually leads to a new age of gold, more or less greener than the past [Geels (2013), Peretz (2013)], we indeed can't wait for it to come without doing anything, above all if there is not yet awareness about what 'kind of gold' we really want for the future.

This is more true if someone expects the new golden age to be build upon the same paradigms, those that gave birth to the present collapse: << *It is not just that we have lost any clear evidence that conventional economic ideologies and market mechanisms can maintain global prosperity. It is because that this paradigm is delivering huge social inequalities, massive sequestration of wealth in fortress tax havens, persistent unemployment and loss of social contribution in expensively educated young people, and the provable emergence of potentially irreversible transitions in the life support systems of the planet*>> argues O'Riordan (2013).

Vergragt (2013) adds to this analysis that this one is not just an ecological nor a simple 0economic crisis, but it is a greater phenomenon which unleashes a series of unpredictable and devastating side-effects that range from social inequalities to democracy quivers:

[11] Available online:
http://daccess-dds-ny.un.org/doc/UNDOC/GEN/N11/476/10/PDF/N1147610.pdf?OpenElement

<<It seems like a crisis of civilization. It certainly is a crisis of modernity. We are facing fundamental questions regarding the key tenets of the industrial revolution, such as economic growth, work ethics, the meaning of progress, and our relationship with nature. The very ability of the current economic and value systems to deliver decent lives for most people on the planet, now and in the future, is open to question.>>

Is there a possibility thus, to move out of this dark pit in which we seem to be paralyzed?

Inside and outside Academia this subject gave rise to big talks followed by more or less close at hand proposals. One of the most controversial is the **Degrowth** solution, which in Schneider et al (2010) words means: <<Equitable downscaling of production and consumption that increases human wellbeing and enhances ecological conditions at the local and global level, in the short and long term>> thus promoting the new paradigm that <<human progress without economic growth is possible>>.

Five Propositions for an Energy Transition

1. **Increase resource productivity** by taxing energy extraction and use, rather than focus on labor productivity.
2. **Discourage energy waste** by either taxation or regulation, and promote **increasing efficiency**.
3. **Direct intervention of Governments** with policies that prevent financial bubbles and income inequity, enhancing transparency on financial flows to tax heavens.
4. **Intense decarbonization** both at national and international level (thus preventing the economic costs derived from climate change).
5. **Encourage investment in non-fossil fuel-based exergy production and use** by promoting practical dialog between academic experts on energy and the long-term investment community (insurance companies and pension funds).

Adapted from Ayres et al (2013)

Others don't want to give up the idea of economic growth but try to integrate it in a sustainability vision. Ayres et al (2013) for instance analyze the direct relationship between money and energy and make five propositions for an energy transition, based on the entanglement of the economic-ecological-social system. (See box on this page).

This subject is thus really complicated, and maybe is one of the most fitting examples of a multi-scale question which unavoidably requires a transdisciplinary and systemic approach.

4

SUSTAINABILITY AND AGRICULTURE:

AGROECOLOGY AS A FORERUNNER TRANSDISCIPLINE

The first pressure that Mankind as applied on Earth is certainly agriculture. Therefore an analysis of the relations and factors that such an activity creates between Man and ecosystems could be exemplifying of the anthropic impact on the environment.

If ecology is seen as one of the first scientific discipline with a systemic view [Caporali et al (2010)], Agroecology adds to that also a truly transdisciplinary approach [Caporali (2010)] that makes it a forerunner of Sustainability Science.

The core element of Agroecology is evidently the concept of **Agroecosystem**: it owns the same salient characteristics of a traditional ecosystem {a tight network of interactions between biotic and abiotic elements and functions [Tansley (1935), Odum (1971), Caporali et al (2004)]} but has a deeper anthropic footprint and a complexity hence, which creates great and ever-growing differences confronted to the natural ecosystems [Altieri et al (1983)]. The utility of the agroecological science lies thus in the ability to provide a quiet thorough vision of the entire system which constitutes the rural reality, and to find the correct solution for the related problems.

The agroecosystem indeed, as Caporali (2010) recalls, has the double nature of <<***real*** *ecosystem modified and used for agricultural purposes, as well as a* ***model*** *that represents it*>>. This allows us to study its components and processes, along with the interactions it has with with the rest of the environment, and thus evaluating its sustainability.

This approach can be applied (with the help of all the other disciplines possibly related, like economy, sociology, geology and many others) to multi-scale phenomena, from global to smaller scales like the Farm itself or the very field. In this vision the farmer is not a mere "supervisor" nor a "planner" of agricultural activities, but it's a core element of the system: first his choices affect the outputs that will emerge from the agroecosystem, than they affect the outputs of the agriculture in his village, insert in a wider region and so on, until the choices of a single farmer will influence the national and even global tendencies.

This kind of relations, nevertheless, is more often reverse, but cases are not rare when relations between actors are much more complicated than that, as shown in Fig. 10. The

GMO subject seems in fact to be a real Sustainability Science problem (pollen drift which contaminates environment outside the GM field, uncertainty on GM food health, farmers rights ecc), even more if we look at Italian situation. In the last few years, as shown in picture, the choices of multinational companies, international organizations and single farmers, have been so tangled that a solution which will fit every actors' needs will be really hard to find, unless Politics will avail itself of a systemic science.[12]

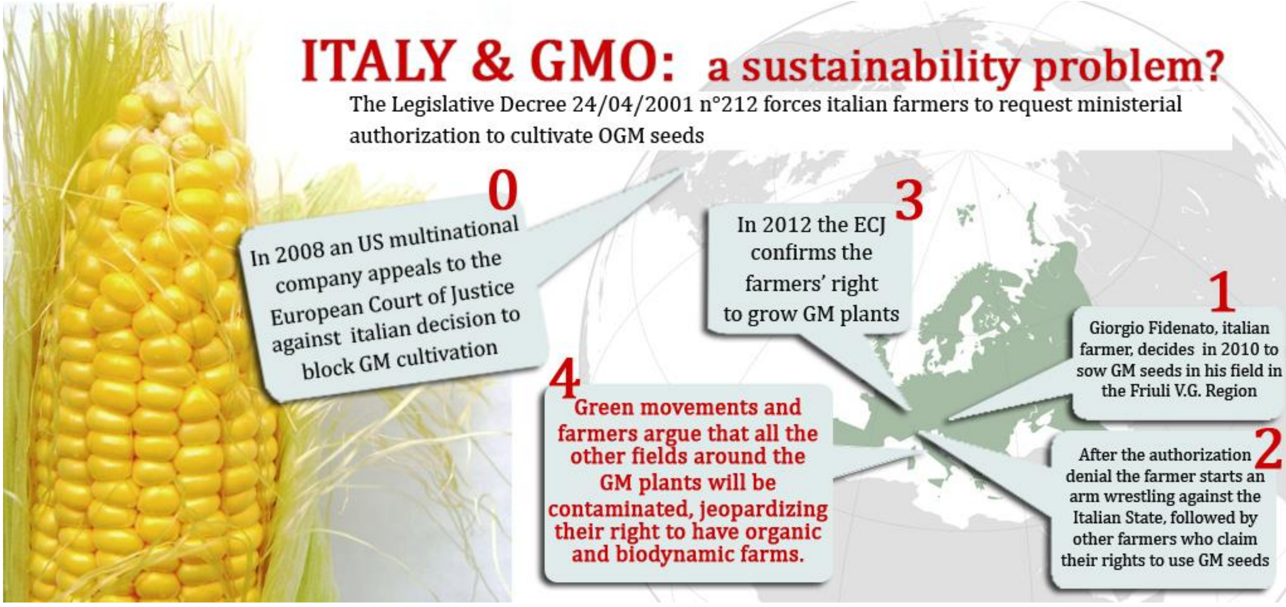

Fig. 10 – Interconnections among multi-scale actors, from the single farmer (1) to multinational organizations (0, 3)[12].

Going back to the original discussion, why can we define Agroecology as a transdisciplinary science and thus a Sustainability Science forerunner?

Caporali (2010) emphasizes its relations with other disciplines and the benefits that those have brought to the research field, arguing that <<*The area of agroecology enquiry is now really operating as "glue" at a transdisciplinary level, bridging the gap between different disciplines and between theory and practice of agriculture*>>. But if we take a look back to par. 2.2, we'll see perhaps the most important evidence of the transdisciplinary nature of Agroecology, and its close kinship with S.S.: the **stakeholders involvement**. This is true in

[12] Image explanatory of the main interconnections active in the question of GM cultivation in Italy, not intended as a thorough analysis of the problem. References to the facts reported, see bibliography.

Image created by author, pictures taken from WikimediaCommons:
Corncob: Author darwin Bell [CC-BY-2.0 (http://creativecommons.org/licenses/by/2.0)]
World Globe: Author Ssolbergj derivative work: Dbachmann (Europe_(orthographic_projection).svg) [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0), GFDL (http://www.gnu.org/copyleft/fdl.html) or GFDL (http://www.gnu.org/copyleft/fdl.html)]

two ways. First of all agriculture is a peculiar science, in which the main actors (farmers) usually overlap with the stakeholders (consumers). In addition to that, as a Science Agroecology has evolved following two different tracks, that very often match: Academies and Society. The evidence of that is the ever-growing amount of Agroecology-related courses, from Universities to many, more or less in-depth, courses organized within the civil society[13] but usually with the contribution from academic staff.

That stated, the new Sustainability Scientists shouldn't do anything but take inspirations from existing models.

[13] The amount of associations and organizations which offer Agroecology-related courses is so high that a complete review of them is not possible here, an example can be found on the website: http://www.agroecology.org/Activities.html (visited on 02/11/2014)

V

SUSTAINABILITY AND SOCIETY

The societal enthusiasm for a scientific discipline like Agroecology is part of a broader interest towards sustainability-related themes. Usually the People got their pulse on the situation much before Governments do, and that's another reason why stakeholders' involvement is so important. The Sustainability question is much more complicated than that though, implying the vision of a "Planetary Society", since, as already recalled in this work, a sustainability transition is possible only in a multiple scale from local to global.

This means that while developed Countries are now facing, within their frontiers, the problem of sustainability (problem that their very policies have created during the last centuries, affecting but the entire Globe), least developed countries have to struggle twice as much: first to improve their status among other nations, achieving those goals they have been precluded for years, and then try to solve or at least contain those tremendous environmental problems caused by others within their boundaries.

Fig. 11
Brand of the Transition Network

As van der Leeuw (2012) recalls, while in developing countries <<*people's well being is tied more closely to natural resource availability, and an increase in development is desired for the fulfillment of basic needs and wants*>> developed countries continue to demand a fictitious high quality of life, consuming high volumes of energy and material, and discharging all the following damaging effects on the less fortunate.

But globalization and technological innovation means also that information is faster than ever, and much easier to access (save only because of political issues). This fact allowed people worldwide to become more and more aware of the global and local challenges that were affecting others, creating a sort of 'global social conscience' which helped to give birth to a big amount of movements, associations, etc… claiming a more sustainable present for everyone.

One of the best known movements in this frame is the **Transition Network (TN)**, which has already in its name two core characters that are required now to address these challenges.

TN, as written on their website, is <<*a charitable organisation whose role is to inspire, encourage, connect, support and train communities as they self-organize around the Transition model, creating initiatives that rebuild resilience and reduce CO2 emissions*.[14]>>

So it is nothing more than a group of citizens, aware of the present dangerous situation, that in front of the political stillness and ineffectiveness about it, decided to join and do their own part to make a change, in the local, to reach the global. Their first appearance indeed was around 2006 as local organization in Totnes, Devon, under the name of Transition Town Totnes (TTT). The first issues they addressed were dependence on fossil fuels and communities resilience in the Totnes town and district. After only one year with an ever-growing number of participants, the project extended as a network aiming to spread worldwide, and by 2014 there are projects related to TN in each Continent.[15]

<<This new 'melded' landscape, characterized by the emergence of large populated regions interacting with their hinterlands and beyond, in ever-more complex and kaleidoscopic patterns, represents our urban future. There is no escape from it>>

Hans van Ginkel, 2008

The goodness of such a movement lies not only in their principles and goals, but in their very nature of organization born in and for a Town.

This is in fact another element of vital importance in the Sustainability question. With the rural population over-passed by the urban one (see Chapter II) all the actions towards sustainability shall be planned in synergy by Politics and Science paying specific attention to **urban issues.** Cities may be seen evidently as multi-scale systems, with a high level of complexity growing with their size. [Han et al (2012), van Ginkel (2008)]. This is even more true when we think about the high rural migration that will emerge into the combined effects of urban overcrowding (and its consequences) and rural depopulation with all the related disruptive effects on ecosystemic services and food supply security [Matuschke (2009)]. << *It is likely that the proportion of the global population not producing food will continue to grow, as will the*

[14] https://www.transitionnetwork.org/about
[15] https://www.transitionnetwork.org/map

number of middle and upper income consumers whose dietary choices are more energy- and greenhouse gas emission-intensive (and often more land-intensive) and where such changes in demand also bring major changes in agriculture and in the supply chain. >> [Satterthwaite et al (2010)].

Moreover, if we refer to the stewardship of soil as discussed in chapter 3, with a decrease in rural population, and an increase in the global one, it is likely that the primary production will be demanded to highly intensive and overexploiting agricultural systems, with the side effects we already discussed, like land degradation, biodiversity loss etc…

That's why it is so important the emergence of societal movements which are addressed both to agro- and urban- sustainability and that international politics start having these issues in the front-rows of their agendas.

S.S. once again could act the needed synthesis between these two levels.

6

SUSTAINABILITY SCIENCE INSIDE ACADEMIA

Today S.S. has essentially an academic frame. Though quiet well-structured.

Among the world of Science it is represented by a **Journal**[16] founded in 2007, published by Springer and edited by Kazuhiko Takeuchi, Vice-Rector of the United Nations University, Director and Professor in Integrated Research System for Sustainability Science at the University of Tokyo. The Journal now hosts almost 250 articles distributed in 19 issues published quarterly. It boasts an eminent editorial board constituted by personalities from the main Universities and Academies in the world and is published on behalf of The **Integrated Research System for Sustainability Science of the University of Tokyo** (IR3S) and the United Nations University (UNU).

The IR3S[17] has been the first official 'common house' for the new born sustainability scientists. Created in 2005 as the first interdisciplinary research project at the University of Tokyo, IR3S after 4 years hosted the first of four **International Conference on Sustainability Science** (ICSS), which are now leading to the constitution of the **International Society for Sustainability Science** (ISSS)[18]. After Tokyo, first Rome in 2010 [Sapienza University-CIRPS (Interuniversity Research Centre on Sustainable Development)], followed by Arizona State University in 2012 and Aix-Marseille University in 2013 hosted the ICSS in the world, while three other venues have been organized focusing on sustainability issues in the Eastern Countries as **ICSS- Asia** (Vietnam National University 2011, Australian National University 2013). In October 2014 in Copenhagen the International Alliance of Research Universities (**IARU**) will host the first **Sustainability Science Congress** .

In Europe the S.S. is represented by the **European Sustainability Science Group**[19] (ESSG) formed by researchers and consultants in the fields of global change and development research from seven Countries inside and outside Europe.

Single Nations also are watching the birth of National Societies for S.S. like Italy, where in October 2013 in Turin has been officially presented the **Italian Association for**

[16] Available at: http://www.springer.com/environment/environmental+management/journal/11625
[17] http://en.ir3s.u-tokyo.ac.jp/
[18] http://sussci.org/
[19] http://www.essg.eu

Sustainability Science (IASS) which in its foundation Manifesto points out six area of interests that shall characterize its activities: 1) epistemological and methodological aspects, 2) innovation and decision-support to civil associations and economic enterprises, 3) governance and democracy, 4) relationship between productive sectors and scientific knowledge, 5) education and training.

All the Societies presented here are obviously quiet new, and therefore still suffer with little participation and visibility, but since the themes addressed are so important and the public opinion is evermore committed to the subject, this situation is likely and hopefully about to change very soon.

A great help, next to the social awareness, is the flourishing of graduate and post-graduate programs in many Universities worldwide, in addition to the Sustainability-related Research Centers like (only exemplifying list) [20]:

- Lund University Centre for Sustainability Science (SW)
- Stockholm Resilience Centre (SW)
- Stockholm Environment Institute (SW)
- Sustainability Science Centre, University of Copenhagen (DK)
- International Centre for Integrated assessment and Sustainable development (ICSS), Maastricht University (NL)
- Institute for Environmental Studies, Free University of Amsterdam (NL)
- Dutch Research Institute for Transitions (NL)
- Potsdam Institute for Climate Impacts Research (PIK), (DE)
- Institute for Advanced Sustainability Studies (IASS), Potsdam (DE)
- Institute of Geography and Geology, Ernst Moritz Arndt University of Greifswald (DE)
- University of Osnabrück (DE)
- Leuphana University of Lüneburg (DE)
- Science, Society and Sustainability (3S) Group in the School of Environmental Sciences of the University of East Anglia (UK)
- Sustainability Science at Southampton (SSS) (UK)
- Sustainability Research Institute, University of Leeds (UK)
- Centre for Sustainable Development, University of Cambridge, (UK)
- Oeschger Centre for Climate Change Research, University of Bern (CH)
- Centre for Development and Environment (CDE), University of Bern (CH)
- International Centre for Trade and Sustainable Development (ICTSD), Geneve (CH)
- International Institute for Sustainable Development, Geneve (CH), Canada
- Sustainable Europe Research Institute (SERI), Vienna (AU)

[20] Upgrade by Author of list on Jäger (2009)

- Institute for Managing Sustainability, University of Econmics and Business, Vienna (AU)
- Inter-univerity Research Centre for Sustainable Development, Rome (IT)
- Universitat Politècnica de Catalunya’s (UPC) Research Institute of Sustainability, Barcelona (SP)
- Dalhousie University College of Sustainability, Canada
- Stellenbosch University’s Sustainability Institute, South Africa
- Global Institute of Sustainability, Arizona State’s University (US)
- Australian Research Institute for Environment and Sustainability, Macquarie University, Australia
- Sustainability Research Centre (SRC), University of the Sunshine Coast, Queensland, Australia
- University of Tokyo
- United Nations University Institute for Sustainability and Peace (UNU-ISP)

7

SUSTAINABILITY SCIENCE FROM THEORY TO PRACTICE

The theoretical frame around S.S. is thus shaped. But after more than 10 years since its first cry, how is S.S. really implementing its good forewords?

Many authors recognize the necessity to structure and operationalize [Ness et al (2010)] the field, to define principles and methodologies by which the new approach can be efficiently applied [Lang et al (2012)]. Nevertheless as Brandt et al (2013) point out, transdisciplinarity is a concept of ever-growing interest among the scientific community. These authors indeed made a review of transdisciplinary papers found analyzing the Scopus database on a time span of 41 years from 1970 to 2011. They concluded thus, that this methodology is gaining an increasing success among scientists, and to enforce it they propose five issues to tackle:

- Adoption of shared and coherent research frameworks;
- Increase awareness on transdisciplinarity in established scientific disciplines;
- As an approach, transdisciplinary research should not enclose itself inside a specific glossary or procedures, rather stay as clear as possible to promote the inclusion of stakeholders from civil society;
- Increase efficiency by developing a broad suite of shared methodological tools;
- Increase practitioner involvement.

But moving over from theory means also to be effective and start reaching goals. Van der Leeuw et al (2012) seem to spread the echo of silence in response to Kates’ question to a <<*room of prominent sustainability scientists: “what sustainability problems have we solved during the last decade*?”>>. They point out one of the obstacles to effectiveness of the S.S. nowadays in the real core of the Academia, which in their words is affected by <<anachronistic pedagogy, inertia and disciplinary insularity and isolation>>. This interpretation is shared also by Wiek et al (2012) which add to it that much effort needs still to be made to enhance the characters that would make such a (trans)discipline stand out among the others: to be solution-oriented and to involve society.

The synthesis of these considerations can thus be concentrated in one loud plea to the present and prospective sustainability scientists: ***come out of the labs!***

7.1 Turning theory to concrete action: a modest proposal

Before being a scientist, everyone is a man, or a woman. Therefore the responsibility on a scientist' s shoulders is double: he needs to act as a Man sharing a Planet with millions of other living species, and as a scientist he is aware of all that this implies. He cannot pretend. Most of all he knows that the "safety" of Academia hallways probably won't be so high to protect him from the next mega-disaster (which someone defines 'natural', ignoring the human-induction). In addition to that a sustainability scientist has the gift of a systemic vision which (unfortunately?) makes him even more aware of the global complex and critical situation, and that in the Era of the Great Acceleration [Steffen et al (2007)] one action of one moment is enough to unleash a series of massive and deep chain-effects that could affect the other side or even the entire surface of the earth in a blink of an eye.

That stated, how can we start to play our part beyond creating knowledge?

Here is a proposal which could ideally **help Sustainability Science to finally express its very potentialities**, bridging the gap with Society and becoming an effective instrument to help Politics address these hard times, from the little village, to the Planet: create a "**Register of Sustainability Scientists**".

Every scientist from every discipline could join it, as long as he agrees to a sort of '**Hippocratic Oath to the Earth**' with the characters of a real contracts by which he/her declare his/her commitment to find a possible and effective solution to sustainability problems, working honestly and without prejudice side by side with colleagues from other disciplines, sharing its knowledge with them and with the stakeholders.

The Register could be divided both on a science-field and a geographical base, and should be represented only by a **website**, freely accessible from everyone, everywhere.

The website should have a **virtual front-office** to which Public Administrations, committees or simple group of citizens could submit a sustainability question.

Then the question should be evaluated in the shortest possible time by a **Commission** (general or local, depending on the case) which will judge the salience (is it really a sustainability question?) and the relevance (What does it imply? Does it have relevant effects? In what scale? Ecc…) of the problem issued.

After the question has been positively evaluated, the Commission will make a **Call** to the scientists on the Register according to the scale of the problem (the call will be addressed to scientists in a specific Region if it is a local problem, then to the ones in a specific Nation and so on). The call aims to the creation of a 'Sustainability Team' or a 'Team of Sustainability Scientists' (better not call it the 'S.S. Team') which will tackle the question.

In the Call the question should be clearly defined and exposed to the addressed scientists, so that everyone could **first voluntarily** apply to enter the Team, if he/her considers his/her field related to the question.

If the Team cannot be created with volunteers the Commission should start a **designation process** (which criteria should be properly defined) after which the designated scientists are compelled to join the Team (one of the terms of the Oath) unless for valid reasons (judged by the Commission on criteria to be defined).

Created the Team, this could **self decide** the tools and methodologies to apply in the research and evaluation process, but the whole process and its progress should be clearly **published on the website** in a specific section of it and in a language understandable by citizens.

The **transparency** of the entire research process is fundamental. It guarantees that the Team won't have any external pressure, that the process will go on as fast as it can and society could play an active part in it. Citizens which consider themselves involved in the question discussed, could sign up to the section of the website dedicated to the specific research project and then be allowed to interact with the team, with considerations and suggestions that could be helpful to it. In addition to that, other scientist could see the progress of the works and give suggestions, improving the transdisciplinarity of the process which is also based upon the integration of knowledge.

The whole operation (the creation of the website, its implementation, the Commissions, the Team, the research process etc…) **shall not be supported by public money, nor by citizens**. Because the sustainability problems are social problems, the money needed could be collected through real and effective fines to the 'creators of unsustainabilities', from seizures derived by criminal activities and from volunteer financing. None in the Register could get a salary unless he/her is a member of a team or of a commission (which are financed through short-term contracts based on the research project), all the possible efforts shall be done to minimize to the backbone costs and wastes, not to weigh upon the community.

This is just a seed sown with the hope that someone will help him to germinate and become a beautiful and useful plant. The Register is now only an idea that shall be improved and well structured, and obviously fundamental question shall be resolved before it becomes operational. But the transdisciplinarity lies also in the process of shaping the Register and its functions. So welcome management engineers, economists, political and social scientists, programmers and all the experts of the possibly related disciplines: let's play our part in this big sustainability challenge and start to act.

CONCLUSIONS

The disquieting frame of Planet Earth during the Anthropocene is thus drawn.

We also pointed out a useful 'tool', Sustainability Science, which could contribute to mitigate the disastrous effects of such a careless management of the World by Mankind.

What else remains to be done?

Act.

This is unavoidable now. But maybe at the end of the work a consideration needs to be made. And it concerns the very meaning of the word Sustainability. Shall we go on and talk about respect for the future generations, or should we add to that also respect for the present ones? We keep on talking about <<prospective stakeholders>> [Anderson (2012)], but the consequences of such an irresponsible behavior of past generations are being deeply and widely felt **now**.

Maybe than we should rethink the essence of sustainability and thus redraw the strategies we want to implement to reach it.

Furthermore as the same Anderson (2012) recalls, <<*sustainability is anthropocentric*>>.

But in a world populated by millions of species, a world that is now universally recognized as a system (and thus the species on it are elements deeply interconnected with and within this system) shouldn't we really apply a systemic vision and consequently consider that in our proposals to improve sustainability?

The answer is hard to find, but S.S. could be helpful also in this case.

Sustainability Science is born and grown up covered by many expectations. It still has a long way to walk, but as the time runs nowadays so fast, it could also give it a positive acceleration to improve and fix what is left to be fixed. But we need to remember that S.S. is not the all-in solution to the Evil on Earth, nor a magic wand to restore the Paradise Lost. It is a new way of seeing problems and address them, giving the correct interpretation and a suggestion on how to tackle them. What is really left to do now is to make people aware of it, learn to talk to society and make it become an essential part in the research process, **we can truly help the world, only keeping our very feet down to it.**

ANNEX 1: SUSTAINABILITY KEYWORDS

HOLISM: coined in 1926 by Jan Smuts, who in his book Holism and Evolution defined it as *"the tendency in nature to form wholes that are greater than the sum of the parts through creative evolution."* It respresents the way to analyze a problem or a particular situation, by looking not at the single components of it, or their sum, but pointing attention to its wholeness and the relations and interactions between the parts, using a systemic vision.

TRANSDISCIPLINARITY: A reflexive, integrative, method-driven scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge.[21]

RESILIENCE: the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. (UNISDR-United Nation Office for Disaster Risk Reduction)

TRANSITION: born in response to the worldwide crisis which affected all levels from environment to society and economics, the Transition Network aims be <<*one manifestation of the idea that local action can change the world; one attempt to create a supportive, nurturing, healthy context in which the practical solutions the world needs can flourish*>> (www.transitionnetwork.org). It is one of the most representative societal movements made from citizens who want to take action rather than over-think the need of structural changing in the relation between society and environment. But in a wider meaning transition is one of the most used word in all the papers referring to sustainability science, as it embodies the necessary step between the unsustainable past and the hopefully sustainable future.

ANTHROPOCENE: Defined first by Paul J. Crutzen, it represents the present geological Era, started in the late eighteenth century, in which Mankind has imposed itself as one of the greatest forces on earth. Its footprint are so deep on the Planet's surface, that scientists are covered with the heavy task of leading society towards environmentally sustainable management[22] in order to avoid unpredictable and unwanted side effects.

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Fig. 10 References

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