Intersecting planetary health and planetary boundaries reveals the double challenge of agriculture and global physico-chemical deregulation

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Clearly identifying and characterizing challenges is crucial in defining priorities and allocating limiting resources[1] for their implementation. Research must serve to increase human understanding of those challenges and the knowledge of objective interdependencies among them.
The resource concept constitutes a unifying theme across disciplines and sectors, such as the SDGs[2], a first order "leverage point" for systemic change[3]. It therefore can become the most parsimonious instrument to address the issue of planetary health[2] .

The planetary boundaries concept is a complementary lever defined as a safe operating space for a sustainable humanity[4] by setting limits (warning signs, thresholds, and regime shifts) to a series of biological and geo-physical variables that contribute to global functions and cycles of the Earth system. Transgressing such boundaries through the misuse and misallocation of resources is leading to perturbation of complex ecological and physico-chemical equilibria to a degree beyond their natural resilience[5]. The geo-physical and chemical boundaries can be rather accurately quantified (typically, CO_2 concentrations, ocean acidification, material and main chemical flows, energy stocks and flows, and water use), while the ecosystem components (i.e. the genetic diversity and ecosystem functional diversity, ecosystem stocks and changes in stocks, ecosystem services, etc) are more recalcitrant to quantification[4].

The approach has sparked interest within the scientific, societal, and political spheres[6] [7]. Defining the interconnectedness within bundles of boundaries makes it possible to articulate them so as to further clarify the issues at stake and give meaning in political and societal terms. **Here we show that the framework can be trimmed down to a two-component system: agriculture and physico-chemical deregulation.**

Agriculture is the main resource provider (labor) and consumer (land use change, biomass appropriation etc.) of all time. The corresponding land conversions constitute the "largest geo-engineering project" in which mankind has ever engaged[8]. Agriculture as food system[9] concentrates the main stressors of planetary boundaries: changes in land and water systems, ecosystem alterations, fertilizer chemical flows, air and water pollutions, climate change. More specifically, agriculture entangles key bio-geophysical interconnected building blocks of the biosphere - biomass, soil, and water. They are stranded assets[10] that need protection from environmental and management related risks through policy-decision making. This is important because the geopolitics of biomass, water, and land is driving the new resources scarcity agendas[11] [12] causing conflict between national security and international order instruments and mechanisms. In particular, land degradation is costing an estimated 10% of the annual global GDP and is directly impacting the wellbeing of more than 3 billion people[13].

Global physico-chemical deregulation is a pervasive and systemic hidden challenge being generated through ocean acidification, more general atmospheric, land, and water pollutions, waste accumulation, and climate change. Note that chemical intensification has been at work on a day-by-day basis over the last several decades: anthropogenic chemicals amount 144,000 distinct products, with a 500-fold increase in volume and a 24-fold increase in assets[14]. This corresponds to a mega-pollution system consisting of complex cocktails that add to the natural chemical world[1] and change over space and time. That makes it hard, or even impossible, to measure, understand, and control a

process in which limits - up to which organisms or ecosystems can safely cope with additive or multiplicative risks posed by the combination of multiple factors - have to be estimated with regard to exposure to any single factor.

First, simple cocktails of as much as 5 compounds showed additive to synergistic effects in cultured cells or biomarker and genotoxicity response tests[15]. A detailed knowledge of the response to all possible combinations of risk factors implies dividing the limit value for an individual threat by the square root of the number of threat dimensions. Even though this would be unrealistic in practice, it suggests that the adoption of limit values two or three order of magnitude smaller than those estimated by single factor impact studies[1] is relevant to legislation. Second, the physico-chemical deregulation is a wicked problem: lack of reference norms for cocktails operating since decades in evolving environments and bias in monitoring methods with improving sensitivity and accuracy[1]. Third, prevention protocols, standards, and legislation are hardly adapted to the scale of risks that remain largely unpredictable and even inexpressible.

Agriculture and physico-chemical deregulation act in synergy and are first order systemic risks to planetary health[2]. For example, the health and economic burden of conventional food systems and global pollution amounts million deaths and $ trillions annually[16 17], in particular in low income countries. We argue that the ensemble constitutes the systemic great challenge with which all societal and political levels must engage over the next decade: ***the health bubble***. However, while most problems and risks in food systems can be tackled, those embedded in the global physico-chemical deregulation appear more like *terra incognita* to science, politics, and society.

Thus, we call for coordinated measures targeting planetary health through:
- Coherent chemical simplification (effectively reduce, redesign, and recycle) in transitions to resource - sober and - efficient societies (see also the Planetary Health Watch initiative[18]). This also contributes to slowing down climate change;
- Shifting around “productivity first” by integrating sustainable agriculture practices into food system transitions[9] with priority on land tenure, value, and land-use planning based on ecological landscape approaches[19], and the food-health nexus[16];
- Systematically and systemically addressing over-consumption, a stressor of both agriculture and physico-chemical deregulation, while reframing green insurance and investment.

These measures are at the apex of further changes in joint environmental and societal policies that articulate physical and social boundaries[6] in a resource stewardship approach guided by simple, universal, and indivisible principles in support of a civilization contract [2, 8]. The issue is to measure costs for society according to no action versus partial-to-complete phase-out of large sets of chemicals and unsustainable practices in order to align equity in health and wealth within the limits of the biosphere. The inclusive health concerns can dictate legal frames that enable fair access to and allocation of resources, a process for which the World Health Organization[17] and the International Resource Panel[2] should be jointly mobilized.

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