Soft Matter View on Global Population Dynamics

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Soft Matter refers to microscopically distinct systems that can spontaneously self-assemble, from liquid crystals, polymers, critical liquid to bio-materials. They are governed by weak inter-species bonds, and then they are extremely sensitive to endogenous and exogenous impacts. The phenomenal hallmark is the set of universalistic scaling patterns for isomorphic physical properties.

Active Soft Matter extends this concept to systems composed of interacting elements that can individually consume energy and then collectively generate motion or mechanical stress. It links such systems/phenomena as bacterial colonies, tissue formation, gene expression, and collective motion in bird flocks, animal herds, schools of fish, and bee swarms.

Very recently, the concept of Intelligent Soft Matter has emerged at the intersection of Active Soft Matter physics, Biology, and Cognitive Sciences. It has been referred to as 'intelligent' materials with self-healing abilities, as well as human crowds or Artificial Intelligence (AI) - driven robotic swarms.

Following the above, the lecture considers the global human population growth, within a model planetary system, as a specific sub/category of Human Active Intelligent Soft Matter. It is implemented by scaling Human Population growth since the onset of the Anthropocene (10 000 BCE) using extended equations developed for Soft Matter dynamics. Notably, a supporting distortion-sensitive protocol has been developed that employs the analytic per capita relative growth rate (RGR) to detect and validate scaling preferences in subsequent epochs. Such extended scaling analysis has been carried out for exponential Super-Malthusian equations and for the Critical-type dependence, recalling the famous 'Doomsday' report by von Foerster (1960). One of the most striking results is the following dominant scaling pattern in the Industrial Revolution epoch:

$$[(1680)\ critical\ scaling \longrightarrow 1968\ \longrightarrow 'reversed'\ critical\ scaling (2025)]$$

It is coupled with a unique crossover from an exponential super-compressed relaxation domain, with the distribution-related exponent changing from $\beta \approx 1$ to $\beta \approx 4$, to the stretched exponential relaxation dynamics described by the exponent $\beta \approx 0.85$. The latter is associated with the population growth from 3.6 billion (1968) to 8.3 billion (2025). The crossover $\beta > 1 \rightarrow \beta < 1$ recalls the unique Gardner transition observed in the dynamics of some Soft Matter complex systems, and also supports evidence for the unique 'self-avoiding criticality'.

The link to the global Carrying Capacity concept and significant ecological and historical breakthroughs along the Anthropocene is also indicated. The comparison with the leading demographic model concepts is also presented.

Location: online via Zoom, to get the Zoom link ask dyrekcja@unipress.waw.pl

1. Sojecka, A.A.; Drozd-Rzoska, *Global population: from Super-Malthus behaviour to Doomsday criticality*. Scientific Reports **2024**, 14, 9853.
2. Sojecka, A.A.; Drozd-Rzoska, *A. Verhulst-type equation and the universal pattern for global population growth*. PLoS ONE **2025**, 20, e0323165.
3. Sojecka, A.A.; Drozd-Rzoska, Rzoska, S.J. *Global population growth, carrying capacity, and high-quality foods in the Industrial Revolutions epoch*. Sustainability **2025**, 17, 6827.
4. Drozd-Rzoska, A.; Sojecka A.A. *Critical view on global population dynamics in Anthropocene*. Proc. Royal. Soc. B **2026**, under review, ref. RSPB-2026-1058.