# 6. Socio-ecological foresight - Integrated Digital Ecosystem Avatars - IDEAs

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## Key Concepts

**Digital Twins and Integrated Digital Ecosystem Avatars**. Virtual replicas of living or non-living entities, updated in near real-time through coupled data feeds via Internet of Things technology, are known as **Digital Twins**. The range of applications of digital twins is rapidly expanding from industry to precision medicine (e.g., quantified self) and urban planning (smart cities, responsive cites). Typically, digital twins are deterministic and predictive, focusing on systems about which humans have a great deal of knowledge - often because humans built them in the first place. The term **Digital Avatar** describes applying a digital twin approach to coupled natural-human systems where precise prediction is an unrealistic goal because social-ecological systems can be chaotic and/or the rules of the system are only partially visible. Digital avatars are multiple, competing hypotheses that improve as more scientific evidence is gathered and some avatars are thus falsified. Evaluation of scenarios under alternative environments or policy choices will become possible as computational platforms (integrated digital ecosystem avatars) are developed to integrate best-available knowledge of physical, biological, and social data.

**Social-Ecological Systems** are the emergent property of interconnected **physical**, **biological**, **socio-economic** systems. **They rely on advances in the underlying disciplines, but are also greater than the sum of their parts, and thus represent a field of science in its own right.** Advances in all disciplines and especially the ability to integrate all of these leads to the potential to understand these systems. This transdisciplinary understanding is vital to addressing the grand challenges facing society in the 21st century.

## Scientific Anticipatory Brief abstract

Despite universal concern about the sustainability of critical ecosystem services, **we currently lack the predictive understanding of the vulnerability of socio-ecological systems to climate change and growth in the human population and global economy required for sound policy and management, from urban planning to nature conservation.** Rapid progress toward socio-ecological foresight can be anticipated over the next one to two decades if action is taken towards a novel integration of observations and models across multiple spatial, temporal and disciplinary scales, leveraging global networks of environmental sensors and accelerating computational performance. **These advances will power a disruptive improvement in collective decision-making capacity.**

Global climate models draw on a vast web of physical-chemical observations and socio-economic data, giving us an unprecedented capacity to predict future states of land, sea, and air. By contrast, the world's biological layer remains under-sensed and far less adequately modeled, and our socio-ecological models are easily overwhelmed at large spatial scales. These impediments can be resolved over the coming decade, enabling data- and model-driven collective action to address the climate emergency and sustainable development goals, locally and internationally. **We anticipate a new social-technological fabric for the Earth, a 'planetary computer' or 'avatar' that spans physical, biological, social and economic dimensions at nested scales of governance.** As a decision-support tool, such an integrated digital ecosystem avatar will model future scenarios and **allow us to anticipate disruptive transitions in the socio-ecological system and the effects of local and global policy changes.**

Supporting city planning and management, such avatars or digital twins can lead to cooler cities with better microclimates, less traffic and better quality of life. For ecosystems, modeling will start with scientifically tractable island ecosystems, and as better models for the much more complex biological world are built, they can scale to larger areas. Socio-ecological models of natural and built environments, initially developed for a few select places, can then be extended to wider regions and ultimately the planet. **The most significant scientific and technical challenge is the integration of physical, biological, and socio-economic data and models for an integrated holistic understanding. Socio-ecological models must be transparent and visible to specialists and to the members of society at large.**

## Detailed table overview of trends at 5, 10 and 25 years

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Example of breakthroughs


Leveraging the digital revolution, scientific advances are progressing at different rates in the major domains (physical, biological, social) that underpin social-ecological foresight at local to planetary scales (**Physical models - ecological models - socio-economic models - digital world**)

| 5 years | 10 years | 25 years |
|---|---|---|
| • Socio-ecological avatars for small nodes - such as cities and small islands – and limited predictive capacity, understand links between existing global models and small intensive nodes | • Ecological and biological models will mature, local models will be refined and can be linked to larger networks | • Avatars that allow predictive management and decision making at large scales. Global network of networks. |