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Review

Vulnerabilities of water-energy and food nexus in cities of digital era

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Abstract: The edifice of civilization stands on water-energy-food nexus, speech, trading management and complexity. This paper, presents a mini review of these issues which are the foundations of civilization, and discusses their role in social prosperity. Recent year public discussion emerges that an electromagnetic pulse (EMP) could strike cities due to natural or artificial reasons therefore, we attempt to describe the impact of an EMP from the viewpoint of civil engineering. To do so, we analyze the fundamental parts of civilization in present, their roles, and their functions. Analysis estimates that an EMP will not regress cities of developed world to the 1970s or even in the Middle Ages, but rather before the agrarian era. It is noted that while the developed world will be more vulnerable, the least developed countries, could exhibit more resilience. Additionally, this paper considers the way societies and cities could demonstrate more resilience, framing the need for further research such as: technological adaptation; study and simulations of related scenarios; design of water-energy-food nexus for survival clusters; resilience measures for money, economy, communications, and trading. As we have a very small timeframe of data (less than 200 years) of the appearance and the effects of EMP, we have to study it, even if the wish is that we will never confront it. It seems unreasonable for our narcissistic and wonderful civilization to behave like ostrich hiding its' head in the sand in order to be hidden by this threat.

Keywords: water-energy-food nexus; growth; technology; economy; resources; human progress; electromagnetic pulse

1. Introduction

In order to understand civilization, humans must recognize its foundation to protect its stability. The primary technological advancement of humans was the use of tools and the management of fire, which occurred in the prehistoric era. Although these steps were involved in the well-being of Homo Sapiens, they were not enough to initiate civilization.

The term "civilization" comes from the Latin word "civitas," meaning "city." Hence, a literal definition of "civilization" is "a society made up of cities" [1].

Oxford Reference [2] defines civilization as:

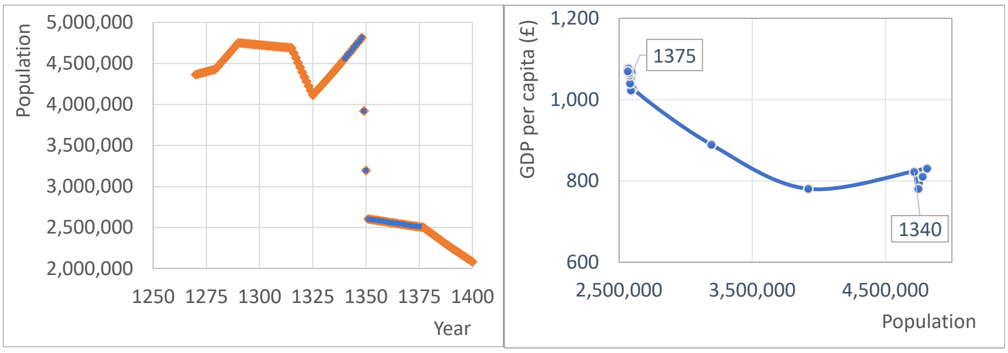
A stage of social development identified by formation of organized communities, permanent settlements, with oral or written records and history, traditions, religious faiths, laws, shared values, customs, beliefs, and artistic achievements.

We note that the definition of civilization includes permanent settlements, which created clusters of humans. As cities lack empty spaces to provide resources, these human clusters had to exploit the natural resources around them, transitioning from hunter-gatherers to citizens. To achieve this, humans had to develop agricultural methods to produce food, hydraulic works to manage water, and find energy sources to efficiently accomplish these tasks in order to compose the vital water-energy-food

(WEF) nexus [3].

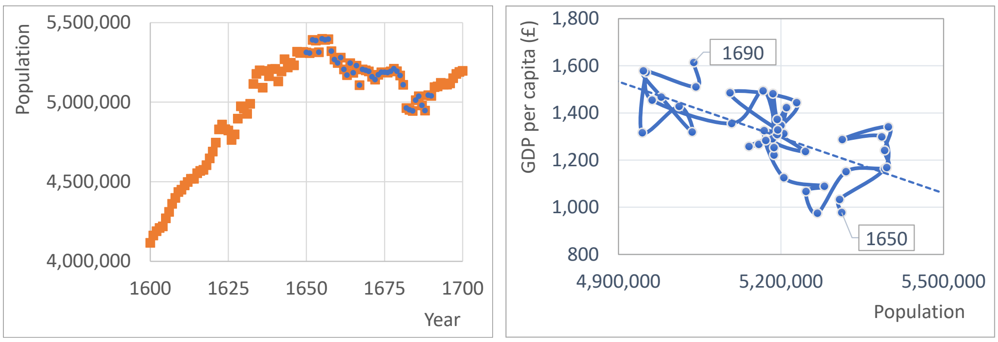
The synthesis of cities necessitates complexity, as houses-warehouses, roads, bridges, and hydraulic works require specialized services, knowledge, and resource management. A prerequisite for this complexity was speech, which facilitated the trading of services and resources, providing the necessary tools for effective management. Wittfogel [4] argued that hydraulic works are fundamental to civilization, as these projects require specialized knowledge, infrastructures, and bureaucratic management of resources, which in turn justifies social stratification [5,6] and despotism.

However, the preindustrial economies operated within a zero-sum framework and were often ensnared in Malthusian traps. Two characteristic examples were the Black Death (1350 AD) and The Great Plague of London (1650–1700). In both cases, we observe that as the population decreased, GDP per capita increased (**Figures 1** and **2**).



(a) **(b)**

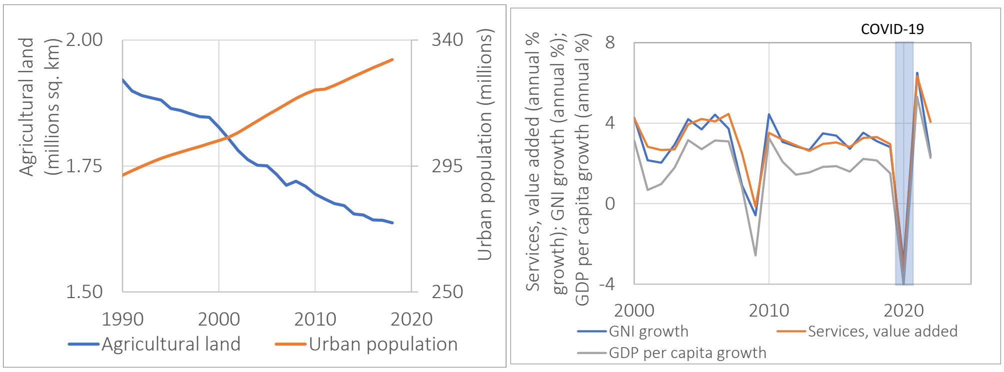
Figure 1. Black death, **(a)** the evolution of population; **(b)** population correlated with GDP per capita [7].



(a) **(b)**

Figure 2. The great plague of London, **(a)** the evolution of population; **(b)** population correlated with GDP per capita [7].

The concept of evolution is rooted in economies of scale, large infrastructures, and complexity [8]. Our complex modern industrial and digital era has enabled humanity to escape Malthusian traps. Tainter posits that societies are complex systems [9] and complexity is a necessary element for their growth. This is evident in the evolution of urbanization in developed regions as Europe over the past several years, within an environment continually enhanced by sophisticated tools [10–12]. In parallel the agricultural land is decreasing (**Figure 3a**). However, within every growing social structure, exists a potential for dynamic crisis and collapse, as complexity may reach a limit beyond which it cannot be effectively managed [13]. Our interconnected world relies on the complexity of created synergies [14], as highlighted by the lessons learned from the COVID-19 pandemic, where growth was abruptly halted globally (**Figure 3b**).



(a) **(b)**

Figure 3. (a) EU. The acceleration of urban population [15] and the reduction of agricultural land [16]; **(b)** global GNI growth (annual %) [17], services, value added (annual % growth) [18] and GDP per capita growth (annual %) [19].

Describing the threat of a strike of an electromagnetic pulse (EMP), Brandt notes [20]:

U.S. dependence on reliable power, electronic systems, and advanced technology has provided both a significant advantage but also created an Achilles' heel.

As technology has provided us with numerous opportunities such as accelerating productivity, facilitating contacts, exchanges, and management, this paper aims to examine how vulnerable our digital era is to an EMP strike (which could occur naturally or artificially) [21,22] potentially leading to a collapse of our digital world [23]. In order to study the vulnerability of cities in the digital era, we will explore the fundamentals of human society's existence and how they could be impacted by the absence of digital tools.

It is referred that depending on the intensity of the EMP, various effects could occur. In this paper, we examine the simplest scenario in which the internet collapses and electronic devices are destroyed, aiming to answer the question: if such an event were to occur, would it guide our civilization back to the 1990s before the invention of the internet, or even further back to the 1970s before widespread computer usage?

Given our estimation that a potential hit by an EMP could regress civilization in developed countries before the agrarian era, we describe the frame of research to enhance the resilience of cities in the face of EMP.

2. Materials and methods

An EMP strike will likely result in problems within the electrical network and in electrical-electronical equipment [24]. As cities are consumers of sources without productive capabilities of WEF nexus, in first we exam the impact of a possible strike to the nexus. In order to understand the function of modern city, we study the fundamentals of pyramid of Maslow [25] and how the city provides the coverage of citizens' needs (**Figure 4**).

Figure 4. The considered issues of the study in the pyramid of Maslow.

Next, we envision cities as clusters of vulnerable individuals who will be without access to WEF nexus. As society and stratification originated from the management of infrastructures and resources, the collapse of networks supplying the vital WEF nexus and the absence of creative capabilities create a bleak scenario for their recovery. Consequently, social peace would become in question.

Despite economies of scale enabling growth in cities providing numerous opportunities and low costs per unit, a city lacking external resources is bound to collapse. Sargentis et al. noted that the dynamic of clustering means growth, while partitioning ensures protection [26,27]. Therefore, we will examine how the partitioning dynamics of cities in developed nations function as survival strategy in a non-digital era.

3. Partitioning of cities

3.1. The big picture

Commencing our examination from the outset, we will delve into the significance role of digital civilization in our society. The productive capability of individuals in the developed world relies on computers, internet and machinery equipment [28]. Consequently, the majority of the population lacks the knowledge to engage in meaningful activities without access to these tools. In a case of EMP strike, this part of the population would find themselves unemployed.

People would come to realize that in the absence of the internet, even if banks withstand the EMP and retain depository records, they would likely remain closed for an indefinite period. Considering that money primarily exists in digital formats as promises [29,30] (in the "belonging" of Maslow pyramid), individuals would be unable to access funds to purchase necessities such as fuels and food. Furthermore, there would be uncertainty regarding the worth of money once banks resume operations.

Cities are significant consumers of water, energy, and food, lacking the capability to produce these vital resources independently (**Figure 5**) [31]. As money and trading would be in question, food and energy will be also in question. The water supplies will be also in question, as management, treatment, and transportation of water rely on energy. Consequently, in the event of a trade stoppage that leads to the collapse of the water-energy-food nexus, cities have few alternatives and are essentially doomed.

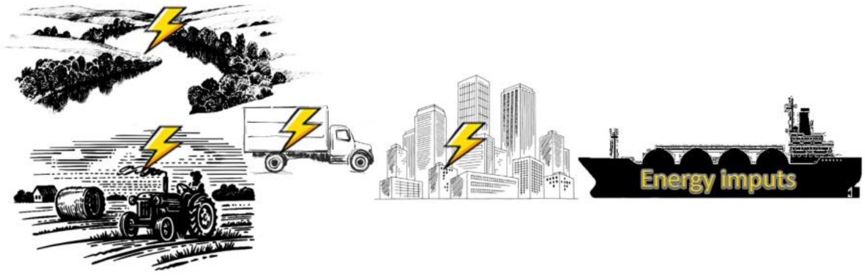


Figure 5. The vital role of energy in the function of water-energy and food nexus.

Many people believe that civilization contributes significantly to environmental problems [32–34] and propose seeking solutions within a Malthusian perspective [35,36] advocating for population reduction as solution for sustainable development. In the case of an EMP strike, this reduction will be enforced.

Current databases indicate that approximately 3.54 billion people, a significant portion of humanity, rely on the surplus of food produced by synthetic nitrogen fertilizers [37]. However, in the absence of trading, the grim reality emerges: with the absence of money, trading stops and the broader perspective reveals that roughly half of the population may not survive.

The lack of trading and degrowth, is also a sentence to death for long-term patience on daily medication.

3.2. The escape roots

The individuals who find themselves in rural areas or fortunate enough to escape from cities to seek food and water in a country-site with essential resources such as agricultural production or freshwater, will soon realize that our remarkable civilization and agricultural practices are not as stable as we would like to believe.

In general, modern agricultural practices in the developed world are energy-intensive, requiring machinery operation for tasks such as pumping water, tilling fields and fertilizers [38,39].

When considering survival in rural areas, it’s essential to recognize that in pre-industrial eras, energy sources primarily relied on animals. However, in the modern era, working animals are scarce in rural settings. Therefore, reliance would shift to fuels for operating machinery such as tractors. Even if some fuels were available, acquiring them would be challenging given the assumption that monetary systems would have collapsed.

Some individuals in rural areas, who are familiar with farming and wildlife could manage to survive but their production will likely be minimal [38], and there will be no surplus to sustain non-productive people.

This simple example highlights how, amidst our narcissism, we often neglect the fundamentals of our civilization. Should a significant EMP strike occur, our civilization wouldn’t merely regress to the 1990s, the 1970s, or even the Middle Ages. Instead, it could potentially collapse to a state preceding even the agrarian era.

Our survival dependents on resources, yet retreating to secluded areas would merely extend the anguish for those deemed “fortunate” within them. Our prosperity thrives on synergies; on a global scale, my welfare is intertwined with the efforts of a

Chinese worker who crafted my computer and a Japanese worker who crafted my car.

Despite potential decrease in life expectancy, the collapse of social stability, and the vanish of our cherished modern routines, the quest for preserving the essential elements of civilization requires envisioning of technological frameworks that can withstand the challenges of the modern digital era, including the threat of an EMP strike.

This involves developing robust equipment and processes capable of adapting to such scenarios.

3.3. The creation of survival clusters

There are handbooks providing guidance on surviving an EMP scenario as a hunter-gatherer [40,41], alongside related guidelines from the US government [42]. While these references may offer temporary individual assistance, they fail to safeguard social structures as a whole.

Obviously, cities as we currently know them would essentially lose their utility in the event of a severe EMP. However, to establish a basic level of societal stability and mitigate the risk of descending into chaos, we must formulate survival clusters. While these clusters may not provide the same efficiency or comfort as our current lifestyle standards, they could function as a means of segmenting cities and, on a larger scale, contribute to the preservation of civilization.

The UN Refugee Agency (UNHCR) has initiated several projects [43] aimed at providing refuge shelters for refugees or inhabitants. In the event of an EMP strike, these refugees would be individuals accustomed to living with high standards endeavoring to rebuild their civilization.

An approach to consider involves embracing the living standards of the 1970s, before the digital era, in regions abundant in resources such as food and water. This would involve manufacturing basic machinery such as cars, tractors, tools, and generators using analog equipment reimagined from their current digital design. The advantage lies in the current affordability of computers and digital components, thanks to robust supply chains and established trade networks. Hence, essential backups could be stockpiled to safeguard against a potential EMP strike.

Another question arises regarding how tools could find spare parts if they were break down. If we preserve our digital culture, our current capabilities could provide a solution by enabling us to 3D print spare parts [44] and establish small production units in each survival cluster.

Even if we could find backup solutions to prepare society for an EMP strike, the big question that lingers is that of the energy sources [45]. While the worth of money, communication, contacts, and trade all uncertain, society must strive for self-sufficient in energy sources. Hence, despite the current lack of cost-effectiveness in small-scale energy converters and storage, multiple efforts should be undertaken to optimize these aspects.

4. Discussion

In the least developed countries, there are communities and individuals who have adapted to living without electricity [46] and digital tools. These societies will be more resilient to the effects of an EMP. For instance, the Carrington Event in August 1859, caused only minor disruptions in communication (telegraph) [47], with minimal impact as our civilization had not yet entered the electrical and digital era. However, the resilience observed in least developed countries does not necessarily imply the extension of our civilization alongside the simultaneous collapse of developed cities.

The developed world, with its narcissistic modern habits will be the most vulnerable in such circumstances. The pervasive incorporation of digital technologies into every aspect of daily life in developed countries, will lead to significant disruptions. Therefore, it's crucial to acknowledge these potential vulnerabilities and plan accordingly to minimize the impact.

In this paper, we have examined the EMP threat in our current era from the standpoint of civil engineering emphasizing our intention to illuminate an existing hazard.

An illustration can be provided as follows: **Figure 6** illustrates temperature variations over periods corresponding to the average life expectancies of a mouse (3 years), a fly (10 days), and a mayfly (20 h). Through their lifespans, a mouse comprehends the diverse temperatures experienced during day, night, and seasonal changes. A fly perceives distinctions between day and night and, if born in early July, might notice a rising trend. Conversely, a mayfly only detects alterations in temperature.

Likewise, within the cosmological timeline of the sun and earth, the observation range and the implications of EMP are exceedingly limited [48]. Despite evidence illustrating the potential devastation of EMP, we lack sufficient knowledge regarding their frequency or magnitude [49,50]. Consequently, we can liken our comprehension of the EMP's impact on our civilization to that of a mayfly's understanding of climate.

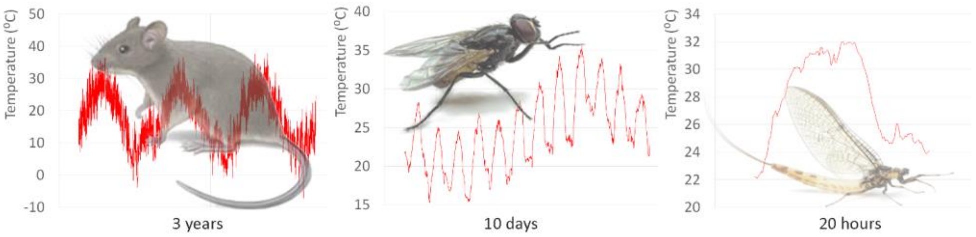


Figure 6. Temperatures in a life of mouse, fly and mayfly (concept: Nikos Mamassis) [51].

Moreover, with the design of EMP weapons [52–54], societies should be prepared to address this threat. Hence, it's imperative to communicate the threat, inform the public, and establish a market for EMP-resistant civilian equipment. Otherwise, a potential strike could swiftly erode social cohesion.

5. Conclusions

This paper examines the potential threats posed by an EMP striking societies, whether natural or technological, from the perspective of civil engineering.

It is estimated that in the event of a possible strike, the resulting collapse could be so profound that it may regress the population in developed cities to a state preceding the agrarian era.

Hence, given the existing threat, several interdisciplinary research endeavors are imperative:

- Technological adaptation to mitigate potential impacts.
- Exploration of scenarios involving varying levels of self-sufficiency.
- Development of a water-energy-food nexus for survival clusters capable of withstanding civilization's collapse.
- Implementation of resilience measures for currency, economy, communications, and trade.

This threat is a black swan who sits next to us in the couch in the living room every day [55], however, we must confront it. It is ironic that we currently face it akin to ostriches, burying our heads in the sand.

Acknowledgments: We extend our gratitude to George Tsakalias for his phrase: "This threat is a black swan who sits next to us in the couch in the living room every day" originally referencing to another issue. However, we found it to be a wonderful, relevant, and fitting addition to our conclusions.

Conflict of interest: The authors declare no conflict of interest.

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