

Science and Sequestration for Sustainability: More Green Space for Less Carbon Emission?

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ABSTRACT

While science and technology are increasing globally, environmental quality is degrading. Ideally, the increase in science productivity should decrease carbon emission; instead, carbon emissions have rapidly increased, fuelling the vicious cycle. This essay tackles this dilemma with three points based on descriptive evidence. The first point reveals that the science output has increased, carbon emissions have amplified, and agricultural productivity has decreased. The second point explicates the potential causes, showing that forest erosion has reduced the green space in the world. The erosion of green space in the world has an adverse correlation with carbon emissions and low agricultural productivity. Although science generates innovative technologies to reduce carbon emissions, which is a product of the far future, the already emitted carbon requires immediate attention and solution. We propose greening the land (forestry) can sequester carbons¹, which has multiple merits. Greening space sequesters carbon in the air and increases oxygen for sustainability, and tree plantation can produce commercial products—wood in construction and usage in an institutionalised market. The free market has neglected the depleting forests and green spaces worldwide and the institutionalised market (for example, a% of the wood in the house construction should replace steel/concrete). This institutionalised supply and demand have the potential to transform the vicious cycle into a virtuous cycle. Hence, this essay addresses these three points to highlight that the current state of affairs is not working, shrinking forest/green space reflects underlying causes, and it requires an institutionalised market solution for the input and output of forestry.

Keywords: Science and sequestration; Forests and sustainability; Carbon Emissions & environmental degradation; Institutionalised plantation per capita; Institutionalised market for forest products.

¹ **Sequestration:** the process of green plants absorbing carbon and producing oxygen into the atmosphere

INTRODUCTION

Theories explain that science and technological development should reduce greenhouse gas emissions because science positively correlates with technological development, and technological development positively correlates with economic development. Economic development improves environmental quality, and the so-called Environmental Kuznets Curve (EKC) explains this argument (Dinda, 2004; Grossman & Krueger, 1993). Ideally, the more science there is, the lower the greenhouse gas emissions should be because technologies improve efficiency in energy usage, offer an alternative to fossil fuels, and improve public awareness (Frank, 1997; Nichols, 2008). The number of scientific publications has risen in the world. From 1999 to 2019, the number of energy science publications has increased by 95% (241 to 469) and environmental science by 53% (985 to 1503). Figure 1 shows the patterns of energy science and environmental science (1996 and 2016). Therefore, the scientific progress in energy and environmental disciplines has made visible strides, raising hopes for a decline in greenhouse gas emissions. While scientific publications have rapidly increased in the world, it has not reduced environmental degradation.

The greenhouse gas emissions continue to rise, and the environmental quality continues to degrade rapidly, reaching the critical stage of survival of the climate, communities and creatures (Malik, 2020). The direct hypothesis that science (as input) improves environmental quality faces challenges (Dinda, 2004). The evidence from Figure 2 shows an upward trend of greenhouse gas emissions (CO₂). Plotting them together, the change in carbon emission due to changes in science has some impact. Figure 3 shows carbon emissions per publication (CO₂/Scientific publications), which shows a downward trend of CO₂ per publication. Although it appears a plausible state that development reduces greenhouse gas emissions, two implicit concerns confound this plausibility. First, the decrease in CO₂ appears slower than the increase in science, suggesting that science's duality contributes to CO₂ via industrial development, and it curtails emissions via innovative technologies. Second, the increase in science (and CO₂) translates into decreased agricultural productivity, upon which communities survive.

Figure 4 shows a visible decrease in agricultural productivity due to an increase in CO₂. We mapped the science in agricultural technology and productivity in a plot. The plotted values in Figure 5 show science in the Agri-biological disciplines and productivity in the agricultural sector. Even though agricultural science is going up in the plotted values, agricultural productivity is going

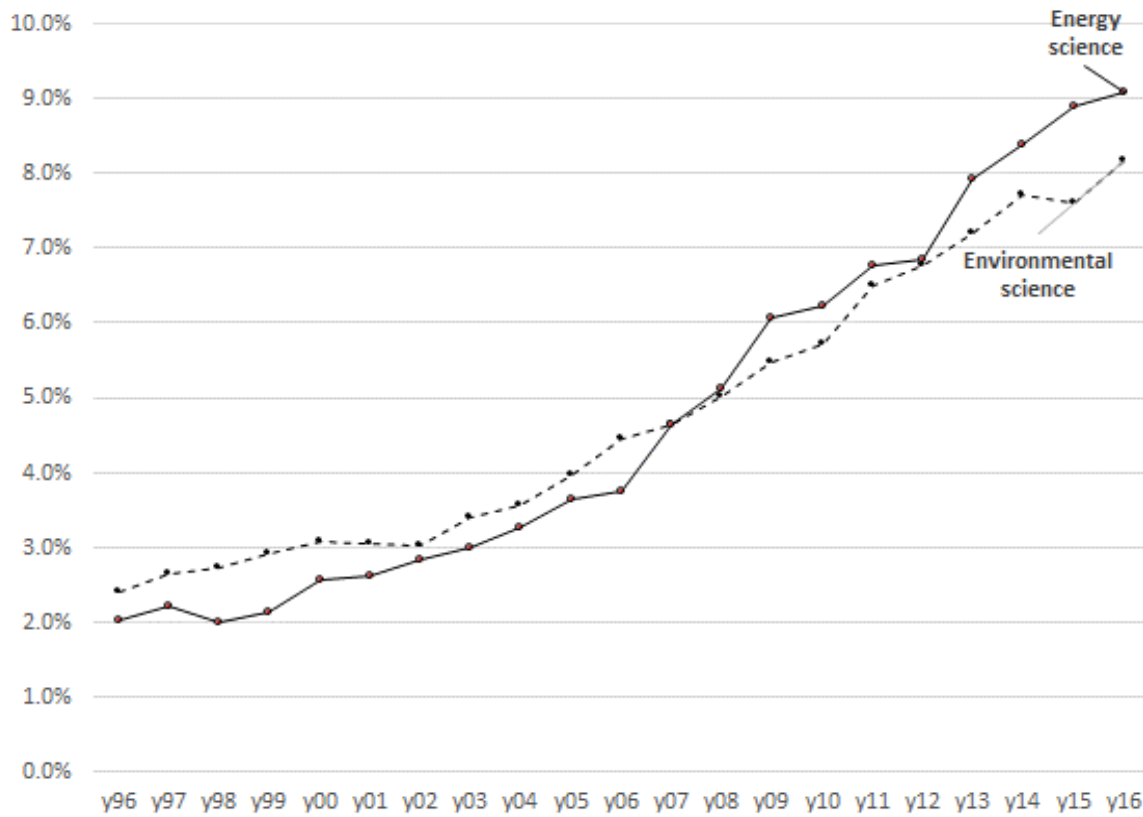
down in the world (Xiang, Malik, & Nielsen, 2020). Indeed, individual countries vary in the CO₂ emission per publication. Appendices A and B show the country-level differences in agriculture (forestry) levels carbon emissions. Since our focus is on greening the space and forestry, we focus on the interaction between the supply and demand in an institutionalised market to increase the green space, plantation and forest. We conclude that the decrease in the green space (forests) increases CO₂, the declining sequestration effect, the reversing the vicious cycle into a virtuous cycle (Blok, 2012). This brief introduction the essence of the vicious cycle's that has gripped the world and pushed it to mortality. In the following, we discuss each of the three points in order.

First, we discuss the dilemma of science and sustainability, as introduced in the earlier section. Second, we discuss the nuances of agricultural science and productivity. Third, we propose that the institutionally induced narratives, 'greening the planet,' offer sequestration potential. The greening of the planet implies that we increase the attention from iron/steel and concrete to woodworks, and the greening absorbs carbon and produces oxygen from the already emitted greenhouse gases. That is that the carbon emissions outweigh the merits of science; the climate and creatures face a threat to survival as green space is contracting; the sequestration of emitted greenhouse gases requires institutionalised markets.

Science and Carbon Emissions

Science and carbon emissions have an intricate relationship. Science refers to all scientific activity and productivity, and technology refers to the transformation of science into artefacts (Malik, Xiang, & Huo, 2020; Pavitt, 2005). This transformed science into technology takes two paths to carbon emissions. One path suggests that science provides new production systems, alternative inputs, and efficient operations. It always creates understanding and awareness among the public. This path reduces carbon emissions, making a negative correlation between science and carbon emissions. The other path takes the alternative route, drawing a positive correlation between science and carbon emissions. Science increases innovative technologies, innovative technologies increase efficiency, and efficiency precipitated industrial activity. This path refers to 'Jevons' Paradox' (Jevons, 1866), implying that science and technology increase pollution rather than reduce it. Descriptive evidence reflects on the increase in science and an increase in carbon emissions in Figure 1.

Figure 1: Science is increasing in the world.



Note: Scientific publications on the timeline

Figure 1 presents scientific publications on two closely related disciplines: energy science and environmental science. Both disciplines show a rapid rise from 1996 to 2016. Energy science refers to publications on energy-related topics, which scientists define as “the ability to do work”². For instance, heat, light, motion, electrical, chemical, and gravitational terms define energy, grouped into stored energy (potential) and Kinetic energy (in function). The stored energy is transformable to Kinetic and vice versa. It means energy has many sources, with distinctive properties as renewable (replenishable) or non-renewable (depletable). The dark line in Figure 1 shows an increasing trend of scientific publications on energy globally, and this trend line leaves

²<https://www.eia.gov/energyexplained/what-is-energy/>

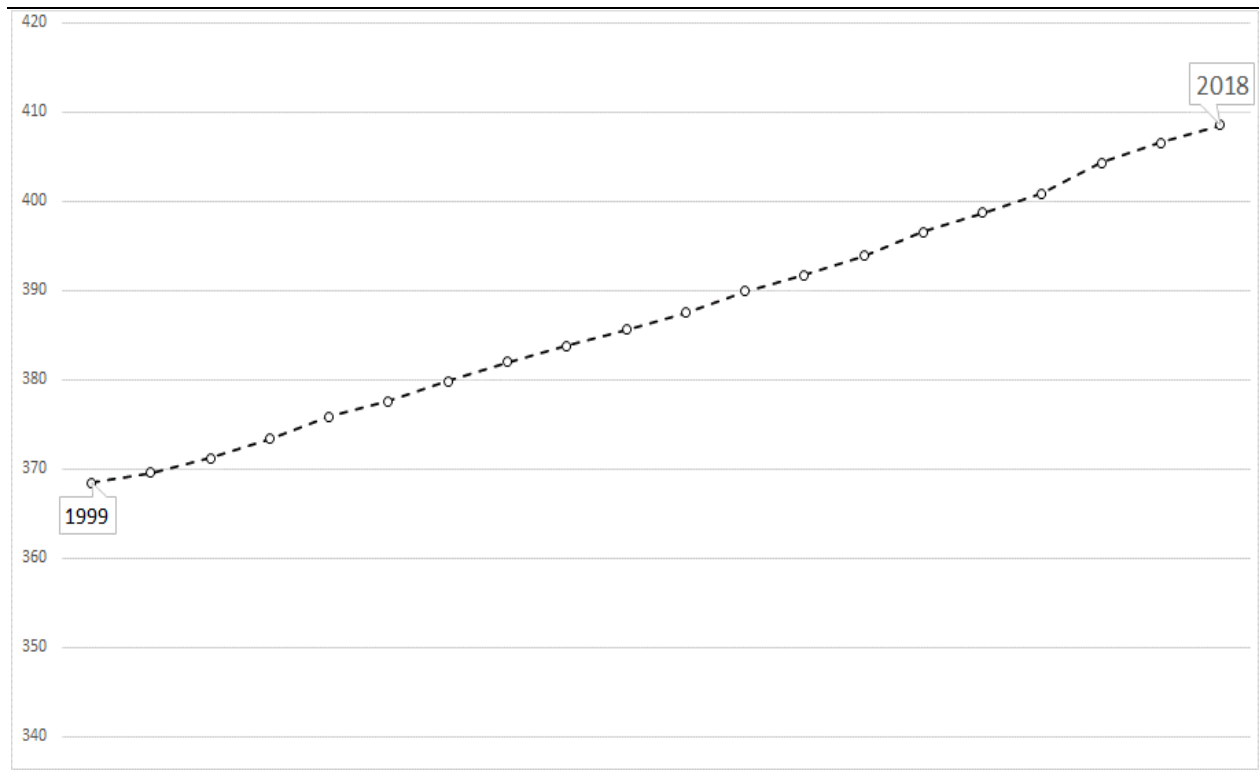
us with a clear view of increasing science on energy-related topics. It coincides with the environmental science trends in the dotted line.

Environmental science, shown by the dotted line, draws on multiple disciplines such as ecology, geology, meteorology, biology, chemistry, engineering, and physics to understand environmental hazard, human impacts and possible solutions³. As a quantitative discipline in research and publications, environmental sciences differ from environmental studies. While environmental science refers to natural phenomena, environmental studies refer to human-environment relations and socio-economic implications. The dotted line in Figure 1 shows scientific publications related to environmental science. Environmental science coincides with energy science, showing that global attention to energy and environmental knowledge has been increasing to better the environment. But has the progress in science led to the desired outcome?

Figure 2 answers, showing carbon emissions from 1999 to 2018 (CO₂). Based on the perceived wisdom, we expected a decrease in carbon emissions. The perceived wisdom indicates that developed economies tend to increase their environmental quality preference, and as the economy develops, the greenhouse gas emissions decline (Grossman & Krueger, 1993; Kuznets, 1995). Indeed, science and technology progress comes from developing economies, and it directly correlates with advanced economies. Ideally, the progress in science should reduce carbon emissions, but the upward trend in carbon emissions echoes the “Jevons’ Paradox” mentioned earlier. We may argue that Carbon emissions are increasing in absolute measures, but not in relative measures. The relative values of carbon emission per publication resolve this issue in the next demonstration (Figure 3).

Figure 2: Greenhouse gas emissions are increasing in the world.

³ Kte'pi, Bill. "Environmental science". *Encyclopedia Britannica*, 27 Dec. 2018, <https://www.britannica.com/science/environmental-science>. Accessed 3 March 2021.

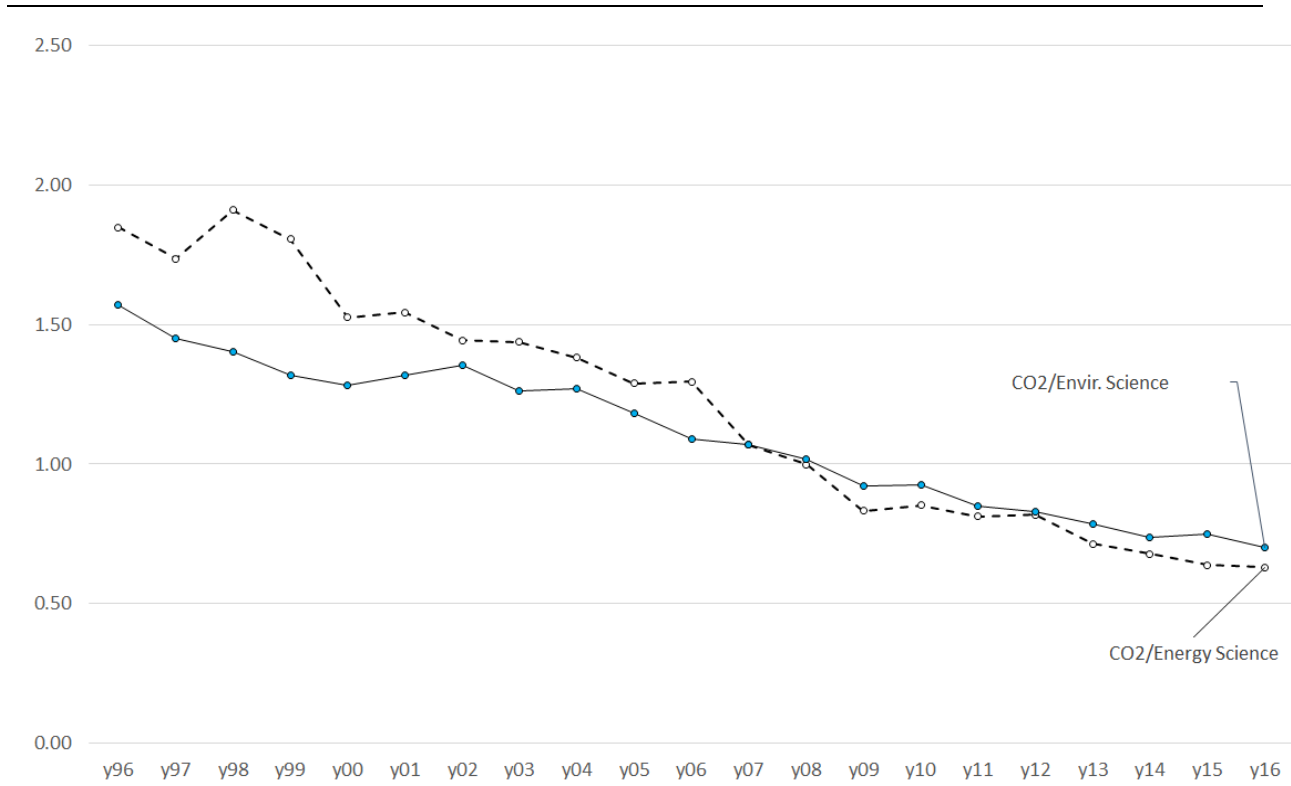


Note: Carbon emission (CO₂) on the timeline:

Sources: Oxford University: <https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions>): 11% (1999 to 2018)

Figure 3 shows the relative decrease in CO₂ due to increased science (CO₂/Science). We separated energy science and environmental science, their relative contribution to CO₂. The dotted line shows the contribution of energy science in carbon reduction (CO₂/energy), and the dark line shows the contribution of environmental science in carbon reduction (CO₂/environment). Both types of scientific discipline show similar behaviour in two ways. First, both disciplines reduce carbon emissions with a downward trend in carbon emissions. Second, both disciplines coincide with the plotted trends, with minor deviations. Before 2007, the era of global economic crisis, environmental science reduced CO₂ more than energy science reduced the CO₂. After 2007 on the timeline, energy science reduced CO₂ more than environmental science did. Thus, the quantity of the global science productivity has mitigated some of the CO₂ emissions, but has the progress in science been able to improve the emitted carbon into the air and improve the agricultural productivity, which is necessary for the survival of the creatures and communities? The next section reveals the answer.

Figure 3: CO2 reduction with relate sciences



Dotted line: Emissions per publication (CO2/energy science ratio) on the timeline
Dark line: Emissions per publication (CO2/environmental science ratio) on the timeline

Carbon emission and agricultural productivity

The second point of this essay rests on the role of the emitted carbon and its correlation with agricultural productivity. Agricultural productivity, foresting and green space is necessary for the survival of creatures and communities. Figure 4 shows the change in agricultural productivity due to a change in CO2 emission (Agri-Productivity/CO2). The downward slope of the trend shows that the increase in CO2 is greater than the increase in productivity.

A recent analysis of the global data shows this correlation (Xiang et al., 2020). Once again, we separated Figure 5 shows the focused attention on agricultural science and agricultural productivity. The dark line shows the trend in scientific productivity in the agriculture sector. The trend shows an upward slope from 1996 to 2016. Indeed, agricultural science productivity has increased in the world. In the opposite direction, the dotted line represents agricultural productivity

in a downward trend, from 1996 to 2016. After 2012, the agricultural productivity falls lower than the scientific productivity on the timeline. Thus, the opposite trends in Figure 5 confirm that science is not helping the environment, and something else is happening in the environment. We anticipated that the world's green space is shrinking, shedding some light on the underlying reasoning.

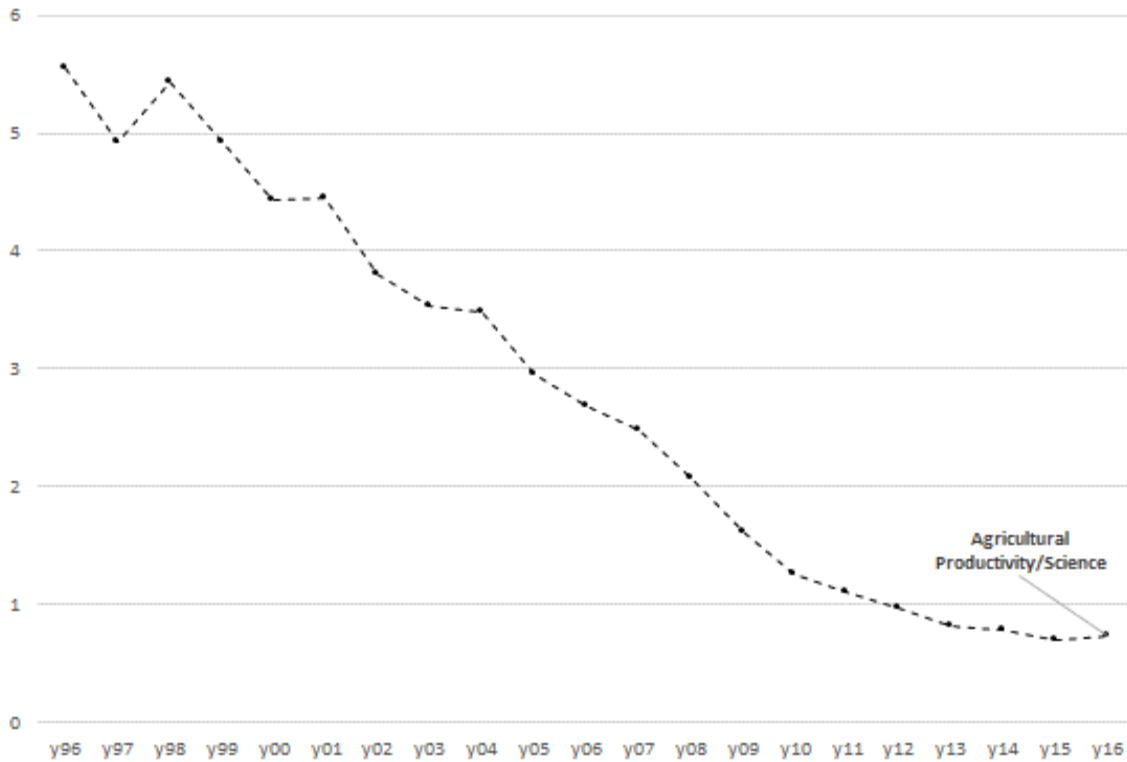
At this stage, two inferences come to the fore. First, the global increase in science neither sufficiently reduces carbon emissions nor sufficiently increases productivity to justify the carbon emissions. The earlier section dealt with the first inference; the following part deals with the second inference—the science-agricultural productivity correlation.

Figure 4: Productivity decreased due to CO2.



Note: Agricultural productivity per CO2 unit (Productivity/CO2). Either CO₂ is increasing more than productivity, OR productivity is decreasing faster than CO₂ emission.

Figure 5: Agricultural productivity relative to agricultural science and technology



Note: The dotted line shows the productivity-science ratio (productivity per publication).

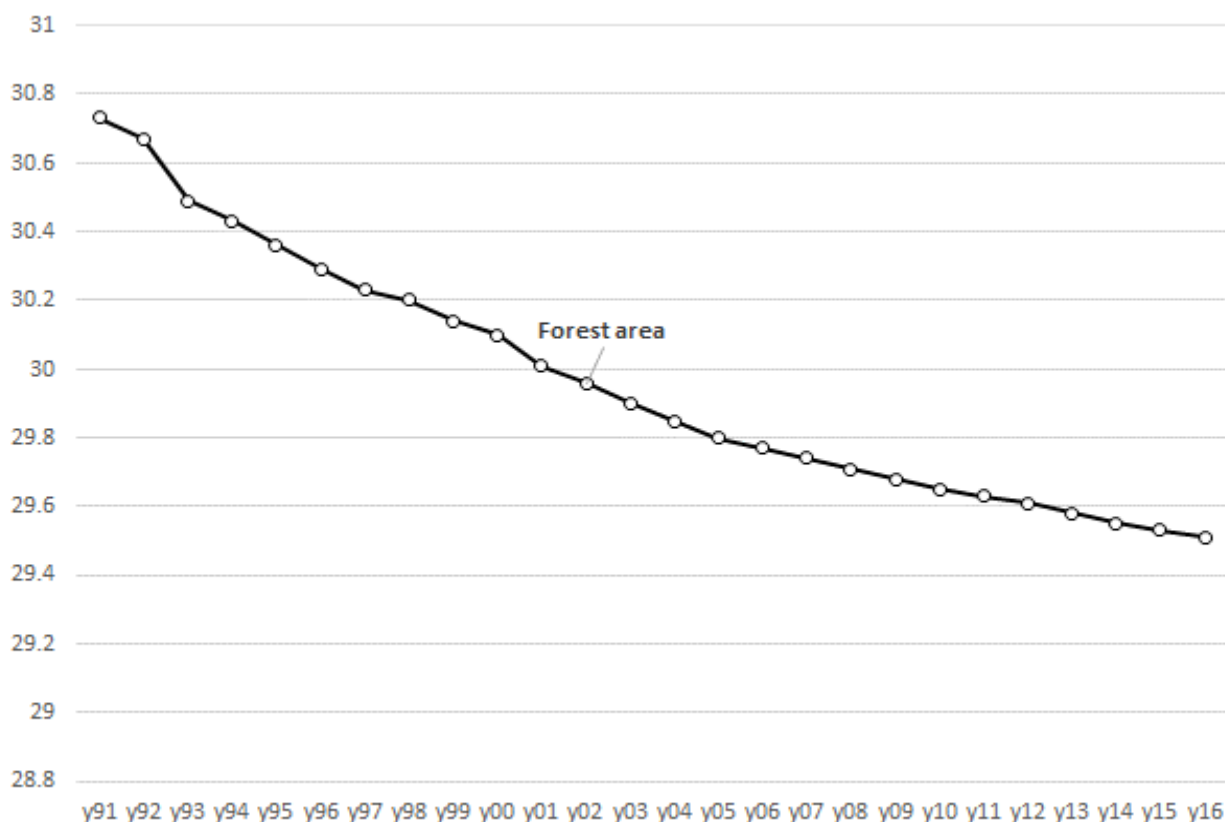
Following the logic presented earlier, we can anticipate that the agricultural productivity and science ratio (productivity/science) offer insights. The dotted line depicts a decreasing trend of productivity per publication (1996 to 2016). At the beginning of the timeline, the productivity factor is 5 units per publication; at the end of the timeline, the productivity factor is less than 1 (0.73) per publications. Indeed, science has not saved productivity in the field. The natural question is why agricultural productivity, which is essential for survival as a source of input (food, air, oxygen, and environmental conditioning), is depleting despite all the progress made in science and technology. We anticipate the answer from the shrinking forests and green spaces, which we will refer to as ‘foresting’ for short.

Depleting Foresting

Figure 6 shows the change in the forest and green spaces of the land area in the world. As a percentage of the total land area, we used data on forests across countries and aggregated the data to obtain the world average. The downward slope of the forest per cent of the land area in the world is fast decreasing. We also show forests and carbon emissions at the country level. Appendix A shows the cross-country comparison of CO₂ emissions, and Appendix B shows a cross-country comparison of forests. Both estimates are based on 18 years average. Some countries have more forest and less greenhouse gas emissions. Other countries have a less green space and more carbon emissions. Some countries have both—forest and carbon emissions. The fourth category has neither. Overall, the trend in Figure 6 shows that the green space is depleting, and the vicious cycle is in full swing.

Can the reversing process of the vicious cycle of deforestation produce desired effects? If foresting and greening the space can absorb CO₂ already emitted into the air, then the policy instruction is simple—increase the forest. The challenge, however, is the implementation of this idea. The next section offers a suggested solution in the form of ‘institutionally induced plantation’ for sequestration.

Figure 6: Greenland % of the total area



Note: The forest area % of land on the timeline in the world

Institutionally induced greening

The institutionally induced greening refers to the policy-driving market replaces the free-market to sort out the environment. The free-market concept implies that the economies sort their socio-economic problems through the invisible hand of efficiencies. The institutionally induced argument points to the intervention of states in the unleashed hazards in the environment. The environment’s hazard has already spiked mortalities in the world (Vohra et al., 2021). One of the simplest solutions that nature teaches has been recklessly ignored: forestation, greening the space and planting trees.

Indeed, countries have maintained sufficient support for the forestation for sequestration. For example, every tree that falls or is cut down in Singapore gets replaced with a new one. The author observed it happening in the Pasir Ris Park (5 kilometres in Length along the Seacoast), from September 2020 to March 2021, at 5 pm every day for 30-kilometre rides (four rounds). Once

strong wind from the Sea uprooted an old, thick and tall tree on the Pasir Ris Park. Three weeks later, an adolescent tree appeared near the ground zero—transported from somewhere, some institutionally induced nurseries to trees' succession process. Likewise, the succession also took place when the existing trees were cut for any reason. Because of the induced policy for greening the city, foresting and sequestration, Singapore's pollution levels have always remained lower than its neighbours. Indeed, forestation and trees have contributed to sequestration and environmental quality.

China has begun mega projects in the inner parts of barren lands, such as in Inner Mongolia and Xinjiang provinces. Likewise, cities have introduced policies towards greening the space per capita to curb carbons in the air. Chinese cities that have attended to green space per capita have curbed carbons to some extent. The inter-institutional interaction (university, industry, city) interaction lies behind these vicious cycles to virtuous cycles (Malik, Kabiraj, & Huo, 2021). If the induced policy and institutionalised behaviour across countries have changed the virtuous cycle into a vicious cycle that we see in the earlier points (Science and CO2 emissions), there is no reason for the opposite direction. We claim that the induced policy transforms the vicious cycle into a virtuous cycle. We stressed already knowing facts to bring into the attention-structure of the institutionalised tree plantations.

Firstly, trees produce oxygen and reduce carbon. The already produced carbon has shaped the vicious cycle, and reversing it requires institutionalised support in favour of trees. Before innovative technologies replace the fossil, fuel-based energies, the emitted carbon will have caused damage to the cycle. An induced virtuous cycle is the demand of the time. Tree plantation is urgently needed as pollution contributes to 8 million deaths worldwide (Vohra et al., 2021). Secondly, the trees produce woods for industrial usage. The induced policy to use wood (a % of total construction) can reduce steel, cement, and brick production. Thirdly, trees/forest decreases famines because they increase resources for creatures and communities. We know that famines occur in eroded lands and drought-ridden places, but not in green spaces. Fourthly, greening the earth improves the objective well-being (technologies, new markets, and new businesses) and conditions society's subjective well-being (mental health). Fifthly, forests bring rain, and rain supports the virtuous cycle. The list of merits goes on, but unless the induced policy takes hold, the market mechanism is unlikely to reset the vicious cycle into a virtuous cycle.

The following three propositions sum up the main points in the argument. These propositions emphasise sequestration policy, process, and performance. Either science or sequestration alone leads us to a limited solution; therefore, we foresee a combined solution of science and sequestration in our conclusive points.

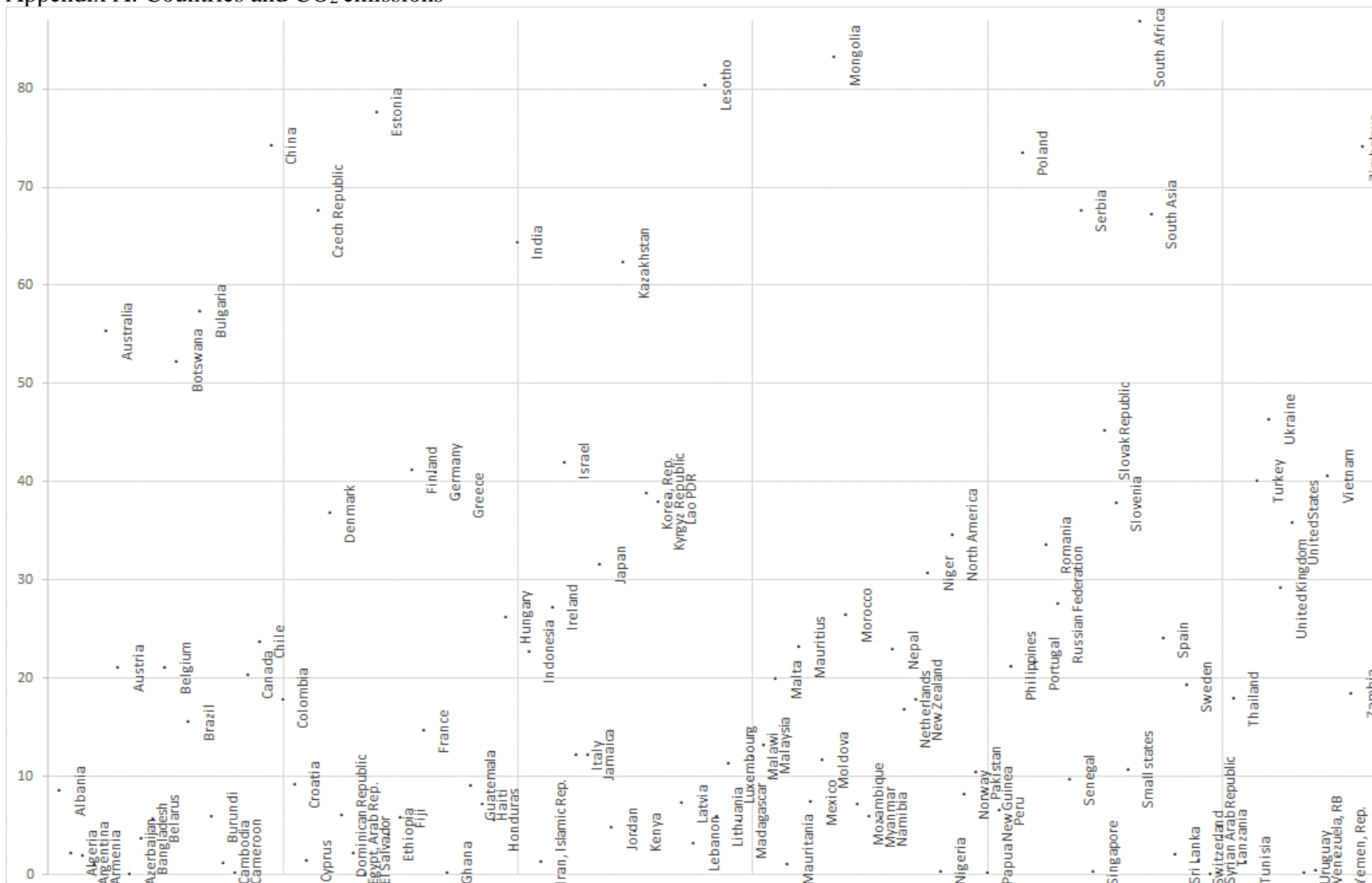
- Proposition 1: Science and sequestration (tree plantation) negatively correlate with carbon emissions.
- Proposition 2: Science and sequestration positively correlate with new markets and entrepreneurship.
- Proposition 3: Science and sequestration positively correlate with subjective well-being.

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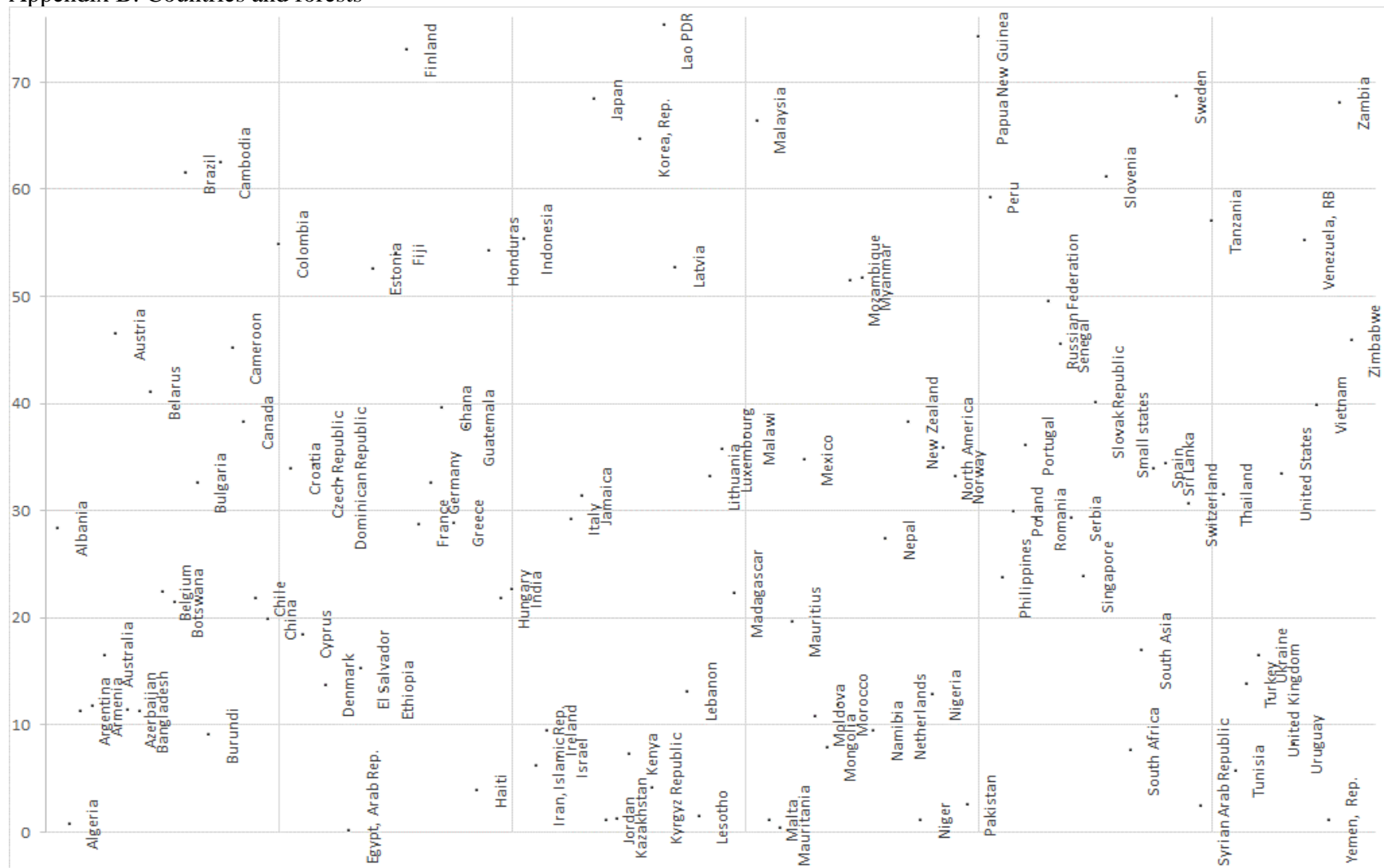
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Appendix A: Countries and CO₂ emissions



Note: CO₂ emission per capita (average of 18 years)

Appendix B: Countries and forests



Note: Forest Area % of land area (averaged 1991-2017)