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Will China be the first to initiate climate engineering?

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Abstract Over the last 30 years, China has industrialized more rapidly than any other society in history and become the world's largest emitter of CO_2. This has demonstrated unprecedented ability to change the socioeconomic landscape, produced great wealth, and led to some catastrophic environmental damage. This is the background that has motivated several authors to postulate that China would initiate geoengineering using solar radiation management. But will China be the first to pioneer climate engineering? The answer, we argue here, is likely to be "no!" We reach this conclusion from an analysis of the historic philosophical tradition that informs the Chinese world view, China's experience of mega-engineering projects both ancient and modern, and the policies implemented over the last 60 years. The debate on geoengineering has to-date been almost exclusively Euro-American, but China has mega-engineering experience, huge resources, and a radically different world-view that needs to be acknowledged. Furthermore we contend that these experiences can be useful internationally in helping to frame the debate on climate mitigation from the perspective of the earth as shared, multiuse and finite.

Key Points:

- China has been suggested as likely to initiate the climate engineering despite strong philosophical and cultural bias against this
- China's history of "gardening" the natural environment means that it sees climate engineering in a different way than that in the West
- Chinese attitudes and experience with engineered environments should be considered, and may provide useful guidance for global governance

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1. Introduction

Humanity has changed the global climate as a side-effect of the energy consumption required to achieve an advanced standard of living. However, most of the world's population has not achieved Western affluence of energy and food consumption, and attempting to do so by business as usual methods would be calamitous for global climate [*IPCC*, 2014] and biodiversity [*Perrings et al.*, 2011]. This is particularly clear in newly developed and developing economies where industrialization has achieved great material wealth for many but considerable environmental degradation [*Liu and Diamond*, 2008; *Bai et al.*, 2014]. An organized response to the ongoing changes climate and ecology by reducing fossil fuel consumption has proved extremely hard to produce, and prompts many in the West to look at geoengineering as a solution [*Hoffert et al.*, 2002]. To the developing world this could appear to be (unfair) avoidance of reducing consumption in the developed world [*Wei et al.*, 2012], and instead choosing to technologically modify the climate for everybody. In this article, we develop some arguments using our understanding of Chinese historical development to provide a novel perspective on future potential deployment of climate engineering by China. The arguments are, of course, somewhat conjectural but we notice a lack of developing world views in the published geoengineering literature and wish to provide some balance to the community that has otherwise been subjected to articles saying the exact opposite [e.g., *Dyer*, 2008; *Victor*, 2011; *Hamilton*, 2013; *Singer et al.*, 2014].

The most radical, controversial, and rapidly acting form of geoengineering is solar radiation management (SRM), [e.g., *Shepherd et al.*, 2009] whereby incoming shortwave solar insolation is reduced (by mirrors, aerosols, cloud, or surface albedos), to balance long-wave greenhouse gas radiative forcing; this is motivated simply because removal of CO_2 from the atmosphere is a very slow process. SRM works — as we know from historic volcanic eruptions, which lower temperatures. SRM will certainly produce regional differences in temperature and precipitation, though such differences in climate models are significantly less than under "business as usual" greenhouse gas emissions climates [*Moreno-Cruz et al.*, 2012; *Kravitz et al.*, 2014; *Yu et al.*, 2015]. Furthermore using it will not return the earth to a previously experienced climate, but to an entirely new climate mode [*Kravitz et al.*, 2013], where greenhouse gases and SRM each drive different diurnal, seasonal, and spatial patterns of climate forcing. Nor can SRM help solve the biochemical issues arising from increased concentrations of CO_2 in the oceans [*Shepherd et al.*, 2009], or directly impact the air pollution faced by China and many developing countries as a result of zealous industrialization [*Chan and Yao*, 2008].

In contrast with U.S. and EU, discussions on geoengineering in China are still at a very early stage. Even among climate scientists there has not been, until recently, strong interest in geoengineering. Many Chinese researchers were introduced to the concepts in 2011 through the Solar Radiation Management Governance Initiative [*Solar Radiation Management Governance Initiative* (*SRMGI*), 2011], which organized a series of meetings in the developing world, including in Tianjin and Beijing. Although in the West is appears that either top-down legislation [*Shepherd et al*., 2009] or a bottom-up measures based on the law-courts may lead to governance [*Larson*, 2015], in China as with other developing countries, the situation is unclear. It is likely that a state's views on transnational governance will depend on their history and philosophical traditions. For example, a Confucian society such as China, may be expected to be far more swayed by elite expert views — which may come from domestic or international bodies, as seems to be the case in Japan [*Sugiyama and Fujiwara*, 2016] — than voices from the lay public.

2. Chinese Philosophy and History

The relationship between human and nature has been central in Chinese ancient philosophy (Box 1). China has a deeply ingrained trait of *not wanting* to be the first in anything. This comes from the ancient Chinese Confucianism philosophy of Ru Jia, which is the dominant lifestyle theory for Chinese people. The core of the system is to be average or normal. The straightest tree will be the first one cut down, and the tastiest well will be drunk dry first. "直木先伐，甘井先竭". In practice this can be seen in the mode of Chinese participation in many international organizations, such as the UN security council, where China seldom initiates resolutions, but has used its veto the least of any of the five permanent members [*Global Policy Forum*, 2012].

BOX 1. THREE CHINESE PHILOSOPHIES ON NATURE

Joseph Needham (called Li Yuese 李约瑟in Chinese) in his monumental work, "Science and Civilization in China" wrote that China is the rational home of yin and yang, of "an extreme disinclination to separate spirit and matter" [*Needham*, 1954–2008]. The roots of this idea go to Three Chinese philosophies, all dating from the Spring and Autumn period of Chinese history (770–480 B.C.) and which are each far more complex and differentiated than can be explained here. All three have aspects that may be applied to climate engineering:

Confucianism, includes the idea of pursuing a harmonious coexistence for Man and Nature;

Taoism, tends to emphasize action through nonaction that is it encourages imitation of the simplicity of nature.

Mohism, though now largely subsumed in Confucianism, emphasized moderation in production, resource utilization and a protoscientific understanding of the world.

These three philosophies underlie the approach of the modern Chinese government to geoengineering: a willingness to act immediately if risk is low, but otherwise a preference for inaction on high risk or low priority issues.

China has had an effective central government throughout most of the past 2000 years [*Xu*, 2011]. However, during the 19th and 20th century, Chinese history was dominated by war and political upheaval. During this period we can assume that short-termism and political expediency often carried greater weight in decisions than regard for cultural traditions. In this context one may wonder how robust is its present policy of openness, engagement, and trade? A comprehensive answer to that question is beyond the scope of the work; however, the successes built on Deng Xiaoping's policy initiatives from the late 1970s, along with better territorial and food security has naturally led toward Chinese policies emphasizing continuity and stability [*Qian*, 2000; *Miao et al*., 2016].

Any person working in China has probably observed an everyday culture of readiness to react to any demand, rather than of preplanning and dealing in timely ways with foreseeable events. This appears to

Figure 1. The site of the Du Jiang Dam in Chengdu which was first established in 250 B.C.

be a great contrast with the long-term approach to central planning characterized by the Five Year Plans. But these may be reconciled by the generally lower fear of making unpalatable decisions in China than in the West, where decisions are often procrastinated until the responsible politician or manager moves on or looses power, passing the (unwelcome) responsibility to their successor. The group leadership in China means that even the president needs to balance the power of office with the retired leadership—which means that they have a stake in decisions long after they leave their nominal posts. This leads to conservatism and an avoidance of novel or risky actions, but also to long-term strategic planning where short-termism is relatively unattractive.

The ancient oriental philosopher and poet Lao Zi (604–531 B.C.) noted that humans should not interfere with nature and should also follow the common rules of the natural world. This philosophy has dominated Chinese society over the long term and also been influential in framing climate change research via promotion of orderly human activities as the path of mitigating climate warming [*Ye et al*., 2001]. China is still largely an agricultural country and its economy has relied on farming practice for a very long time. Breakthroughs in controlling annual river flooding go back as far as 250 B.C. when the Du Jiang Dam [*Li and Xu*, 2006] was built in Chengdu (Figure 1). This made Chengdu the "country of heaven" as the increased irrigation capacity led to the rapid growth of food supply and population [*Li and Xu*, 2006]. Irrigation in one sense disconnected people from the vagaries of climate, mitigating the extreme seasonal variations in water supply, and the consequences of drought. However, it also established the long-term dependence of farmers on continued and sustainable resupply from rains, since extraction from deep aquifers was beyond the technology of the day. As farming reliance on irrigation was established many years ago, the feedbacks between humans and the seasonal climate have long since been established. China was also, until quite recently, an almost closed society with little foreign trade in agricultural goods. This combination of reliance of irrigation and self-reliance, along with the philosophical views of Lao Zi has led to the Chinese landscape being developed more as a garden than as a resource to be exploited, depleted, and resupplied by import of key materials.

An analogy between geoengineering and gardening has been made previously [*Keith*, 2000], though they differ significantly in scope and intention. The suggestion that the Earth's climate may be guided by human hands as is an ornamental garden, could be interpreted as implying that the Chinese mindset would be welcoming to SRM, particularly if it increased productivity of the biosphere. This tension between being part of nature and seeking to control it is central to the view China takes on geoengineering.

Isolationism is the thing of the past. Economic development and international trade over the last three decades has raised hundreds of millions from poverty, but has been fueled by enormous coal burning, accounting for 50% of global consumption in 2012. China, the most populous country in the world, is now also the world's largest greenhouse gas emitter and faces severe air pollution. Historical dependence on coal is dictated by its accounting for 92.5% China's total energy resources. Development of other domestic fossil fuels is limited, but imports of natural gas along with rapid growth in renewable are forecast [*Dong et al*., 2014].

Successive Chinese governments have often repeated that they do not aim to match western lifestyles but rather seek a "reasonable standard of life" for the people. Despite this, there is a common sense that economic growth and material wealth is being achieved at too high a cost to the environment [*Chan and Yao*, 2008]. Public pressure to meet more stringent air pollution standards is already severe and growing — for example, the strict air pollution measures adopted in and around Beijing for the APEC meeting in November 2014 were very popular, and President Xi made promises to achieve "APEC blue" more often in future. The Chinese government had already made very strong pledges to significantly reduce coal consumption creating a huge challenge in replacing coal with alternative energy. These are entirely consistent with the bilateral carbon emission reduction agreement with President Obama in November 2014 that includes cooperation on carbon capture technology [*U.S.-China Joint Announcement on Climate Change and Clean Energy Cooperation*, 2014]. China's commitment to reduce greenhouse gas emissions does motivate it to explore CO_2 removal technology.

3. China's Green Earth Dream

Does China's record of "mega-engineering" make it a likely candidate for initiating climate engineering? Afforestation is one example of a mega-engineering project which can be seen as analogous to geoengineering in some respects — particularly in dealing with the human impacts of very large-scale manipulation of the environment. Since the 1950s afforestation has been a political priority "the green earth dream." One claimed outcome has been reduced number and severity of dust storms which regularly plagued almost half the Chinese population until the late 1990s and early 2000s [*Wang et al*., 2011]. *The Green Earth Plantation Policy* has seen successive Chinese leadership try to manage land use and mitigate dust storms, that led to terrestrial ecosystems in China sequestering 28–37% of its fossil carbon emissions over the 1980s and 1990s [*Piao et al*., 2009]. Starting in 1956 when Mao Zedong initiated "Greening the Motherland" with plantation activities for 12 years, followed in 1979 when Deng Xiaoping began reversing the decline in national forests via "The Three North Afforestation" project, aiming for 23% in 2020 and 26% forest cover in 2050. This has been maintained and strengthened in 1997 by Jiang Zemin and the "Green for Grain" program for converting cultivated land for forest, and in 2011 by Hu Jintao with "Green for Grain" converting pastureland to grassland, and in 2014 by Xi Jinping with "One Belt and One Road" that initiates a balance between development and environment in reviving the ancient silk road.

Afforeststion is far from being the only example of ancient or modern mega-engineering projects. *The Du Jiang Dam* in Chengdu was first established in 250 B.C. [*Li and Xu*, 2006] leading to development of agriculture and prosperity. The modern equivalent is the *Three Gorges Dam*, one of the largest engineering project in China, which required the displacement of more than 1 million people while saving up to 100 million tons of CO_2 emissions per year by producing electricity from hydropower [*Liu et al*., 2008].

The Great Canal from Beijing to Hangzhou was started in 486 B.C. for military purposes and was the longest and greatest canal in the ancient world with a length of 1797 km. It served as a major transportation artery and prosperous settlements thrived along its course [*Luo et al*., 2015]. *The North-South Water Diversion*, which in December 2014 delivered the first water to Beijing will cost twice as much as the Three Gorges Dam and transfer 44.8 billion cubic meters of fresh water annually from Southern China to the arid North through three new canals [*Edney and Symons*, 2013] (Figure 2).

China has 50,000 local communities engaged in cloud seeding. Such weather modification may be erroneously seen as geoengineering. But the objective for the communities is to prevent damage from violent

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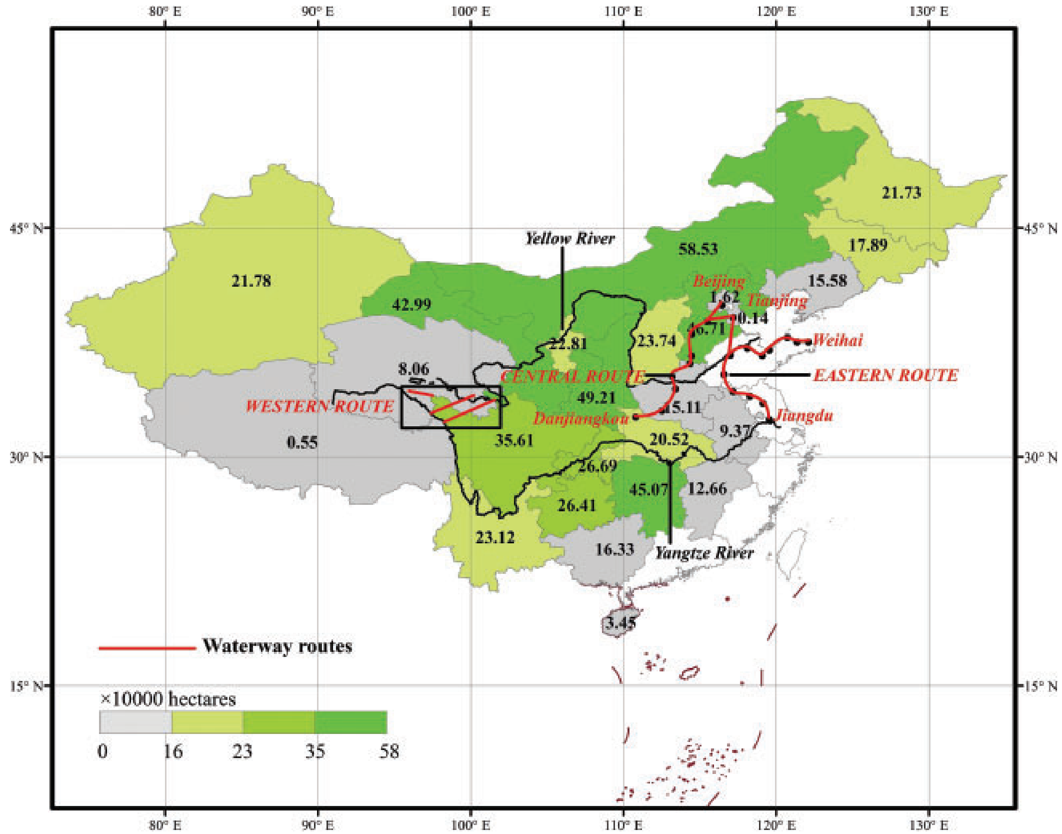

Figure 2. Area by provinces of forests converted from croplands under China's Grain to Green project, and the location of the North–South systems to deliver water to northern China.

storms rather than to make for blue sky days [*Edney and Symons*, 2013]. The motivation for cloud seeding are thus entirely local, and immediate in action, hence it fails the definitions of geoengineering [*Keith*, 2000; *Shepherd et al*., 2009] by lacking both scope and intent. Cloud seeding requires large quantities of precipitatable water in the sky, hence there is no question using it to make rain over deserts or move storm tracks, both of which may be reasonable objectives of geoengineering. However, cloud seeding is an example of how many competing local interests in a particular managed weather outcome are managed, and may provide useful analogues with international governance aspects of geoengineering.

The examples discussed show how China has pursued what could be seen as geoengineering, but of the uncontroversial CO_2 removal type rather than the SRM approach [*Weng and Chen*, 2014]. Land use change and afforestation in this respect have moved the environment back toward sustainable carrying capacities, and hence along traditional philosophical paths (Box 1). CO_2 capture projects have received funding for many years, though they are still in the earliest phases of development and certainly not commercial ventures as yet. The decade of central government discussion, controversy and subsequent reputational damage surrounding the building of the Three Gorges Dam [*Liu et al*., 2008], suggests future government reluctance to initiate technological-intensive fixes for climate such as SRM. Chinese scientists have been reluctant to become involved in SRM geoengineering [*Edney and Symons*, 2013; *Weng and Chen*, 2014]. However, China has just decided to support research into simulations of climate and impact studies under geoengineering climates. Experience in dealing with cloud seeding may also be relevant to geoengineering governance.

4. Geoengineering and the Blue Sky Dream

So will China take a lead role in SRM to achieve the blue sky dream? The record mega-engineering projects discussed in the previous section, and the environmental problems caused by rapid industrialization suggest China may well do so without deep consideration of the global political ramifications. However, we have argued that this is a misleading view and that both the historic philosophy and the present political establishment suggests that this is unlikely to be the case. It is clear that the Chinese tend to view the whole landscape as more akin to a garden than as an entity separate from the people it supports. This may also indicate a willingness to adopt geoengineering—and indeed there is clear evidential support for this via the intensive afforestation programs discussed above, and the ongoing investment in CO_2 capture and storage. There is much less support for SRM which presents the moral hazard of potentially allowing more fossil fuels to be burnt creating more pollution and is perhaps psychologically associated with air pollution, which in common with stratospheric aerosol injection, leads to haze and white, rather than blue, skies. Strengthening the political reluctance to initiate SRM is the criticism experienced in the wake of some mega-engineering projects, and the general tradition of unwillingness to take the lead.

If some climate emergency were to befall parts of China—such as potentially disastrous flooding, that could be convincingly shown to be ameliorated by geoengineering, then of course China as any other nations, would be strongly tempted by it. Chinese ecosystems occupy a wide variety of climates but many of these are relatively continental, with large seasonal cycles and interannual variability in temperature and precipitation. A wider range of natural climate variability leads to resilience, for example, continental glaciers and permafrost are much more stable under climate change than those in maritime environments [e.g., *Zhao et al*., 2014] since they would have been destroyed by natural variability if they were particularly sensitive. On the other hand the relatively high population density of the productive land regions on the eastern plains means that there is little extra capacity to handle food shortages despite a government "red line" on cropland area (1.2 billion hectares), and a planted area of 1.33 billion hectares [*Miao et al*., 2016].

Ever increasing numbers of Chinese reside in cities along the eastern seaboard that are only a few metres above sea level, and hence large populations and vast financial centers are vulnerable to rising sea levels and storm surges [*He et al*., 2014]. If these cities are threatened, then so will many others be across the world [*Nicholls et al*., 2008]. *Weitzman* [2013] has argued that the "twin externalities of climate change"—the need for comprehensive agreement on carbon emissions and the simultaneous ability of single entities to undertake climate engineering—means that large-scale conflict is highly likely in future. To prevent this requires that geoengineering would likely need to be generally agreed on internationally rather than done unilaterally—and even then may be of limited effectiveness [*Moore et al*., 2010]. Agreement on international climate mitigation has not been hampered by lack of scientific consensus, but instead by short-termism and narrow national self-interest. This contrasts to the naturally long-term and inherently sustainable historic world views of much of the developing world. Interestingly significantly more positive attitudes toward SRM geoengineering were found in surveys among Indian, Chinese, and Philippine students compared with students from Japan, Australia, and South Korea [*Sugiyama et al*., 2016], suggesting real differences in attitude between developing and developed world views of climate change and SRM.

China's stance on geoengineering is crucial as the largest developing countries. From the western view, China has unique experiences that in many respects point toward it being the first climate engineer, such as international pressure due to it being the largest greenhouse gases emitter along with relatively high social and economic costs of carbon reduction, advanced weather modification technologies, a top-down political system, experience of large-scale construction projects, efficient decision-making processes, etc. In fact, though all the above reasons are plausible, the reality is that research on geoengineering is still at very early stage. The knowledge basis required to support policy formulation and a transnational governance stance is quite weak. The general public and the bureaucracy have little knowledge or expertise on geoengineering. The first national level project on geoengineering starting in 2015 (http://www.china-geoengineering.org/) pushes Chinese scientists to cooperate closer with the international academic community and take part in international programs. This includes taking part in the GeoMIP climate modeling simulations [*Kravitz et al*., 2013, 2014], and organizing workshops aimed at developing world researchers who can then assess risks and impacts relevant in their own countries. Foci of Chinese research includes the basic processes of geoengineered climates [*Cao et al*., 2015]; impact studies on hurricanes [*Moore et al*., 2015], Arctic sea ice [*Moore et al*., 2014], and glaciers in high mountain Asia [*Zhao et al*., 2016]; and governance issues [*Chen and Liu*, 2015; *Liu and Chen*, 2015].

China is taking a cautionary and open position on geoengineering, which is promising for international geoengineering governance. This involves promoting the philosophical view of human nature harmony where humans and nature are really part of just one system. This world view may well be shared in other countries with Confucian philosophical roots, such as Japan; something which could be explored through international surveys similar to those carried out by *Sugiyama et al*. [2016]. There may be arguments for China to want to adopt SRM early, such as reducing risk of climate impacts or to exert its growing technical and political strength. These would of course be tempered by its history of mega-engineering successes such as the *Green Earth Plantation Policy* and difficulties such as the Three Gorges Dam, and also by its commitments to participating in supranational entities. Thus China, with its experience of the pitfalls that line the path to the "green earth dream," is in a position to play a globally significant and constructive role in building equitable and effective geoengineering governance.

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