Bridging science and policy: building resilience to global environmental and economic change in Brazil

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The complexity of the Food-Water-Energy nexus in Brazil

Brazilian society faces significant uncertainty due to two significant global contextual factors. On one hand, global environmental change, due to global unsustainable energy use and greenhouse gas emissions, is highly likely to change weather patterns, which will affect detrimentally the land cover and biodiversity in Brazil, with severe impacts on agriculture. On the other hand, without appropriate policies in place, the Brazilian economy and environment, relying heavily on exports of natural resources for prosperity, can be vulnerable to global economic change, where changes in demand for commodities could lead to either or both environmental degradation and large scale land-use change, and decreased wealth and employment. Both types of changes are likely to impact and create intricate complexities in the Brazilian Food-Energy-Water nexus. These transformations and forces must be understood in order to minimise detrimental impacts to welfare and the environment in Brazil.

Energy, water and food production and consumption in Brazil face important challenges. River flows and water reservoirs, including in dams, have record low levels and face scarcity, requiring curtailing a predominantly hydro-oriented electricity system (e.g. Watts, 2015). The productivity of the land in many regions is likely to change excessively with climate change due to significant expected changes in rainfall (Phillips et al., 2009), affecting the viability of agricultural practices in the affected areas. The Brazilian economy is highly focused towards exporting agricultural products and food, with one of the highest shares of agricultural exports in the world, as we show below, which makes it vulnerable to global economic changes. The profitability of some types of agricultural production, for instance meat and soya, is likely to evolve with the accelerated or fluctuating growth of consumption in several nations around the globe, which may incentivise excessive indirect land-use changes (Arima et al., 2006) and environmental degradation (e.g. Tollefson, 2015). Increasing land productivity is possible (Strassburg et al., 2014), but will not necessarily happen without policy intervention. These critical issues are tied to one another through the complex Food-Water-Energy (FWE) nexus. Understanding the nexus is key to sensible planning for improving the resilience of the Brazilian economy and environment to internal and global environmental and socioeconomic change.

The FWE nexus is a complex system involving many interactions between social and natural components, of which the future behaviour is not well understood. Effectively, it is not understood, for instance, whether food price fluctuations are related or not with events taking place in the energy sector (e.g. the oil price or increasing biofuel demand). Also, the extent to which the Brazilian economy and environment could be affected by food consumption patterns in other emerging nations has not been quantified. Furthermore, Brazil is known to be susceptible to significant environmental change in scenarios of climate change (e.g. RCP8.5 in IPCC, 2013), especially when combined with deforestation (Davidson et al., 2012) which will inevitably affect its ability to produce agricultural commodities, labour employment in the agricultural sector, regional economic development and ultimately national growth and efforts towards poverty reduction.

A sustainability transition in the FWE nexus involves improving resilience of all of its components, which include land-use, trade, energy production and water management. Understanding the science of these connections is not enough, however, because changes of policy, legal frameworks and regulatory compliance act to influence and re-orient the system in subtle interrelated ways. Such changes, therefore, need to be extremely well informed by science in order not to lead to unintended consequences (e.g. generating energy poverty with emissions reduction...
policy, barring access to water with pricing policies, destruction of ecosystems due to land policy for creating jobs, etc). Thus, a qualified science-policy dialogue can become crucial for informing effective policy-making and environmental law that reach stated objectives.

Four key unknowns require to be illuminated in order to effectively advise public policy:

1. How will global environmental change affect the Brazilian Food-Water-Energy nexus? What are the potential impacts of ensuing water scarcity and land use change on the Brazilian food-water-energy nexus?

2. In which directions will the current trends of global economic change likely lead the Brazilian Food-Water-Energy nexus in 2050 and beyond? What are the socioeconomic implications for Brazil, and how are they connected to the food-water-energy nexus at different scales?

3. Which portfolios of policies, at local, regional and state level, can most effectively incentivise the sustainable development of Brazil, and improve its resilience to the challenges of the food-water-energy nexus?

4. What projects, at the community level, can contribute to improving the resilience of the Food-Water-Energy nexus in Brazil?

**Global environmental change and its impact on Brazil**

Current levels of emissions are leading the world towards significant global warming and climate change, and Brazil is in a particularly vulnerable position. Current consensus at the Intergovernmental Panel on Climate Change (IPCC) on future levels of cumulative emissions and climate change projects the average temperature change to lie between 3 and 6 degrees of global warming in 2100 (‘Representative Concentration Pathway’ RCP8.5, see IPCC 2013), and severe alterations in rainfall, which would lead to severe changes in the land cover and losses of biodiversity. This, however, not only involves changes in average temperatures and rainfall, but also changes that are un-evenly distributed, changes in usual patterns, severe variations (e.g. floods and droughts) and increased frequency of extreme events. Brazil is likely to experience amongst the most pronounced of these effects over its territory.

These changes can be avoided if all countries of the World curb a major proportion of their greenhouse gas emissions. Indeed, according to the scenarios calculated by climatologists, as reported by the IPCC, it is still possible to reduce global emissions rapidly enough to avoid a high probability of warming beyond 2°C. In such a scenario, most patterns of the climate remain unchanged (IPCC 2015), including in Brazil.
Figure 1 shows maps of changes in mean temperatures and rainfall (using data from CMIP5) across the Brazilian territory. It is observed there that in a scenario of continued high global emissions, temperature changes of up to $3^\circ C$ (winter) and $6^\circ C$ (summer) could occur in the Amazonian region, which could severely degrade vegetation and ecosystems in that area. Meanwhile, models project that in such a scenario, rainfall could be significantly disturbed, increasing by 60% in the southern regions while it could decrease by 40% in already arid regions of the north. These changes will have serious impacts to agriculture and food production in Brazil. Furthermore, the energy system in Brazil comprises of a very large complex of hydroelectric dams. These already suffer from variations in water levels which have led to necessary curtailment due to water shortages, which will intensify with climate change. It is not unlikely that failing hydroelectric systems gradually become replaced by high carbon thermal electric plants (coal or gas plants). Such substitution will lead to a decreased sustainability of the energy system, which, similarly to other nations elsewhere, will lead to increased emissions and exacerbate the problem. Finally, increased water shortages due to altered rainfall in climate change scenarios will also lead to increased extraction of groundwater, which could suffer from depletion in some areas.

**Global economic change and its impact on Brazil**

The Brazilian economy benefits to an important degree from lucrative exports of agricultural products and food, accounting for over one third of total Brazilian exports. This makes Brazil one of the countries with highest export shares oriented towards food and agricultural products. Figure 2 displays economic data for Brazil: the top panel shows the export shares of food and agricultural products for several countries around the World. The bottom left panel shows historical exports (at constant 2005 prices) for these products relative to exports of other primary resources (mining, oil and gas), as well as the rest of the economy. Agricultural products and food were making 38% of exports in 2010. The bottom right panel shows employment for the same sectors: agriculture and the food industry have constantly employed around 20% of the working population since 1970. These figures place Brazil in a context of growing wealth associated to exports of natural resources. These industries are particularly vulnerable to possible future environmental changes:

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1 The data is from the CMIP5 archive, created using an ensemble of GCMs (General Circulation Models, state-of-the-art climate models). Where more than one simulation is run with the same GCM, one time series only is taken so as not to bias the ensemble by including more simulations from certain models. The mean of all models is calculated, combining them into one time series. Then a climatological average is calculated by averaging over a 30 year slice all summers or all winters for the future periods a reference period. Changes (anomalies) are the difference between the future and reference period.
depending on the future levels of cumulative emissions, the productivity of farming and crops could change dramatically. In relation to other nations, Brazil does not produce a major per capita contribution to global emissions, and thus although they are as important as elsewhere, emission reduction policies in Brazil alone are unlikely to affect the trend of global environmental change. However, policy-makers in Brazil have to take into account the effects that different levels of environmental change could have on agriculture, and devise policy to improve its resilience.

However, these data signal another important vulnerability of the Brazilian economy. Voluminous exports of natural resources are made lucrative by international prices, supported by high demand in many other nations around the planet, and their growth is notably highly driven by economic growth in other emerging nations such as China. This economic pressure has been well known to strain the Brazilian environment through man-made deforestation and land-use change for the purpose of expanding agriculture, which leads to significant amounts of emissions, and possible land degradation. In this perspective, therefore, changes or fluctuations in the trend of global consumption of agricultural products grown in Brazil (e.g. beef, soya, maize) can lead to environmental degradation and/or economic fluctuations.

Finally, an additional commodity is becoming increasingly exported from Brazil: biofuels (e.g. IEA, 2013). As interest increases for low carbon liquid fuels, an international market is forming for both ethanol and biodiesel. Brazil is well placed to profit from these markets, having promoted many of the innovations in the use of ethanol for transportation. Biofuels can replace the use of oil readily, and thus the demand for biofuels could scale up to as high as 200EJ/y (~4-5 Gtoe/y), the order of current global oil consumption. Such an amount of energy cannot be sustainably produced by the global arable land surface without displacing almost all agriculture worldwide (Hoogwijk et al. 2009). This competition for land between energy and food demand can potentially be strongly felt in Brazil.

Combining global environmental and economic changes: a perfect storm for Brazil

The prospects of both significant and expected global environmental and economic changes combined form a highly uncertain future and possible perfect storm for Brazil. Growing affluence in certain countries leading to sharply increased demand for increasingly meat-based diets, combined to decreasing land productivity due to climate change will most likely lead to high economic pressures for converting remaining forests, natural areas and biodiversity hotspots for agricultural production, and this could lead to severe environmental degradation in Brazil. It could furthermore lead to reduced access to water, energy and increase socio-economic inequality.

Policy for sustainability, resilience, food security, land use and climate change mitigation must be well designed and coordinated, informed by science, in order to be effective. They represent, however, an important challenge, since they involve many sectors that have not in the past been effectively coordinated from a policy standpoint: land-use policy, agricultural subsidies, fossil fuel subsidies, emissions standards, renewables policy, biofuels policy. This will require a new paradigm in policy-making in order to avoid common ‘silo’ thinking, where decisions for specific sectors are taken without consideration or understanding of their implications for other sectors.

Bridging science and policy: supporting the policy-cycle in Brazil

A sustainability transition in the FWE nexus takes place within an appropriate policy context. Policy-makers, however, have constraints of their own, and it is crucial that any scientific information produced with the aim to influence the policy process be fed correctly into the policy cycle with clear understanding of its legal and political requirements and implications, in order to
have a clear chance of success. This demands specialist knowledge of policy contexts and of environmental law (e.g. Vinuales, 2012). Furthermore, understanding the policy cycle in its context requires knowledge of the specific location and culture in which it takes place, requiring the involvement of local experts and contextual knowledge in environmental policy and law.

A scientific impact assessment of policy options from a modelling perspective is highly valuable to policy-makers when it is able to obtain information about the effectiveness of policy at influencing decision-making by consumers, investors, farmers and other agents. Effectively, valuable insights can be obtained this way: in the climate change policy area, time being limited, significant value lies with any ability to predict the effectiveness of emissions reduction measures, especially when their costs and legal/political feasibility are known in advance.

In this context, marrying complex analysis/modelling of high policy resolution with specific expertise in environmental policy and law proves to be the best science-advising work structure. Policy experts then determine, in close collaboration with local policy-makers, which policies could have a chance of success in the local policy cycle, testing these through the impact assessment modelling expertise, and feeding information back to the policy-maker in an iterative manner.

Policy processes are complex and rarely linear, and simply presenting information to policy-makers and expecting them to act upon it is very unlikely to work. On the contrary, showing that policy ‘works’ as part of the policy formulation process, improves the chances of success of policy implementation at various levels. In this respect, setting up real sustainability demonstration and awareness raising projects can also help in demonstrating feasibility, best-practice and engage with the public in order to build consensus over measures envisaged.

Conclusion: determining priorities for applied policy research

Collaboration between researchers and policy-makers has perhaps never been as crucial as it is today, in view of the many critical issues that countries of the World, including particularly Brazil, face in the context of the Water-Energy-Food Nexus. A perfect storm of complex interactions, dependencies and vulnerabilities is most likely to be expected in Brazil, given its current environmental and economic situation. The solution is not to conclude that economic or environmental well-being must be sacrificed. On the contrary, it is possible to improve the resilience of the Brazilian Water-Energy-Food Nexus to the point where its vulnerability to global drivers becomes manageable. This, however, will require significant policy changes well-informed by in-depth research. This can only be achieved through close collaboration between state-of-the-art research and policy-making.

References


