

Think Globally, Organize Systemically

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Whether or not one agrees that the world is flat,¹ it is certainly getting flatter all the time. Increasing flatness is revealed in the swiftness with which everything from information to disease sweeps around the globe, changing habitats, health, economies and cultures. Combined with the increasing requirement for collaboration to address complex issues, this situation has transformed international research collaboration from a luxury to a necessity. Evidence of that necessity is seen in conferences like this one and in the structures of US funding agencies and institutions of higher learning.

The nature of modern research, and the remaining social, cultural and economic diversity around the world combine to make international research collaborations considerably more complex than strictly domestic programs. Moreover globalization in many arenas means that almost any research activity must be considered in the light of a rapidly growing web of interactions which vastly multiplies the number of possible intended and unintended consequences. In this essay I suggest that US research universities are not structured so as to enhance the success of international collaborations, and that integrating systems science into the administrative architecture is a key solution.

Minor complexities and annoyances

In the sciences, it would be difficult to find a researcher at a major research university who does not have one or more interactions outside the US. Such

arrangements range from almost daily information exchange, through student exchanges and active physical collaborations. Federal funding agencies in the US and abroad have entire divisions devoted to supporting such collaborations, and a constant flow of funding opportunities for work abroad crosses the computer desktop of most researchers. Indeed, a successful researcher is often in the position of making difficult decisions about which opportunity to pursue based on what can be accomplished, the difficulties and complications to be encountered, and availability of willing collaborators.

It is not difficult to find potential international collaborators, and a feature of the flattened (electronic) world is that it is not difficult to ask about willingness. What has not been eased is the difficulty in discerning what is actually doable and what complications will occur, and the unintended

consequences that could arise from what seems like a straightforward project. Researchers working in different fiscal, social and cultural environments may not have similar values or views of what constitutes satisfactory progress and what difficulties are tolerable. For example, I once used window-screen cages in a study of insects on plants in rural Argentina. Little did I realize that window screen was a precious commodity in the nearby community, and my project was made impossible because of repeated theft of my cages. On the other hand, daily life in town became considerably more comfortable, a fact that clearly outweighed my desire for a PhD in the minds of local residents.

Minor complications like window screen theft arise from local socioeconomic circumstances, and might not be predictable even to local residents. But many factors that come into play while carrying out research abroad are predictable and well known to experienced travelers and their agents. Examples include importation issues (e.g., need for legal assistance at customs), fiscal issues (e.g., monetary exchanges, existence of cooperative banks), and socio-cultural issues (e.g., bribes). These are all topics about which the average researcher learns entirely from experience, sometimes at some risk. If research institutions agree that international collaborations are important, it would seem wise to establish resources for these programs to ensure their success. This kind of resource is nearly nonexistent.

When these kinds of travel complexities arise for undergraduates studying abroad, most universities and

colleges have individuals or agencies on campus and abroad capable of addressing them (although with variable success). It is quite unusual to find an International Programs office that has a research support mandate; most US universities are addressing globalization at the level of undergraduate education. Researchers planning to work abroad must depend on more experienced colleagues or their international contacts for information about the vagaries of working at a particular locale. Foreign study students have access to substantial detail about their target countries, mainly because they and their parents have demanded it. No such support for research abroad exists at most US universities. In my own example, my French foreign study-experienced daughter is by far my best (only) source of advice about working in France. And while she can warn me about the lengthy vacation periods during which I might not have access to a laboratory she really can't help with more detailed research-based issues.

A survey of the positions of international programs in the organizational hierarchies of US universities and colleges indicates that the international program office is usually led by someone at the Vice Provost or Vice President level and is usually devoted to undergraduate education. Even when international program offices include research support staff, it is unlikely that they offer a very comprehensive understanding of the issues involved in doing research around the globe. On the other hand, international program staff and their contacts abroad make an effort to

provide similarly detailed information to undergraduates going abroad.

Major complexities, orange peels and biofuels

Learning national, regional and local idiosyncrasies is possible, if painful, for the individual researcher or research team. While having access to information about these minor complexities would make program development and research outcomes smoother, in most cases these issues do not make or break a research collaboration and they usually do not have global consequences.

However, there are levels of complexity at which the researcher's focus on his/her project can influence success or failure and have unforeseen consequences at a larger scale unless the work is placed in a global context. There is increasing awareness of the relationship between globalization and research, as seen in federal regulation of the movement of endangered or pathogenic organisms. Federal oversight and warnings issued to researchers have both increased dramatically in response to the demonstrated ease with which such organisms can be transported among countries and continents. Regulatory responses are typically driven by unfortunate experiences or fiscal issues rather than by foresight. As a consequence, investigators need constant and frequent updates on changing regulations and sociopolitical circumstances. Even funding agencies are frequently behind the curve as new regulations (e.g., collection permit requirements) go into effect, so that grants may be awarded in violation of

international or even US policies and laws.

The singular focus investigators bring to their research is important to its success. However, that focus can blind the investigator to the broader context in which the research's findings will be important. As a consequence, results of a "successful" project may turn out to be incorrect or inconsequential or even have a negative impact when considered in the broader context of a flattened earth. For example, Daniel Janzen (University of Pennsylvania) developed a project to reclaim pasture dominated by imported African grasses in northwest Costa Rica to return it to dry tropical forest.² This was part of a decades-long project to restore a large portion of seasonally dry Costa Rica to its original state and expand preserved land there as part of national parks.³ It may be the oldest, largest and most successful habitat restoration project in the world. Janzen's research indicated that mulch with citrus peels suppressed the alien grasses and together with fire suppression permitted the forest to re-establish itself.² Janzen entered into agreements with local citrus processing plants for routine shipments and spreading of peel mulch. This effort was justified on the basis of the argument that natural ecosystems provide 'goods and services' (clean water, forest products, etc.) that can be valued monetarily.⁴ The negotiated agreement with the citrus company valued a range of ecosystem services in specific monetary terms, and a value of mulch was set as "payment" for these services.² This arrangement was in force by 1999, and continued into the 21st century.

I visited Dr. Janzen in April of 2008 and asked how the citrus peel project was going. His answer: "it is over". When I asked why, the following story emerged. Three changes unforeseen by Janzen had occurred to doom the project. Cheap fuel and air fares during the 1990s had made development of resorts, vacation homes and second residences in the area accessible to so many North Americans (a new airport made northwest Costa Rica an affordable 3 hour flight from major US cities) that property values began to exceed the value set on them in the Janzen-citrus processor agreement. In fact, property values increased 10-fold in many cases, making the land more valuable for development than for "ecosystem services".

Then an expanding middle class in developing countries dramatically increased demand for fuel and the price of oil rose rapidly. While air fares followed, air lines suppressed increases and air travel continued. A global response was to invest in production of biofuels, especially ethanol from corn and sugar cane. Brazil has been a world leader in ethanol production since the 1970s and it began expanding ethanol production in response to demand, at the expense of food and fiber plantations.⁵

Finally, a series of hurricanes in 2005-2008 dramatically reduced the production of citrus in the US.⁶ Besides destroying mature trees, these storms carried foreign diseases that directly or indirectly (through hygiene programs) destroyed millions of trees. It will take as many as 10 years for US citrus production to recover to pre-hurricane

levels. Because the US is a major consumer of citrus products, especially environmentally "green" citrus oil cleaners, other nations are in the position of compensating for this loss. In previous citrus downturns (e.g., resulting from frost damage) Brazil was a major contributor to the US citrus supply.⁷ However, the global demand for biofuels has led Brazil to reduce citrus production in favor of ethanol production, reducing its ability to help.⁵

Costa Rican citrus growers saw the US shortfall as an opportunity. The rising land values and the expanding demand for citrus products made it clear to them that the original contract to exchange land value for peel mulch now undervalued land, which was better devoted to expanding groves. Moreover, environmentally "green" cleaners are extracted from citrus peels, and comprise the chemistry that Janzen found suppressed African grasses. Taken together, global trends towards cheaper, greener fuels and cleansers made Costa Rican citrus producers want to keep their peel mulch, extract cleansing agents, and sell the extracted mulch to ranchers anxious to retain the alien African grass pastures Janzen was trying to eliminate. The citrus companies became competitors for land, could afford to pay more than restoration advocates, and hence limited the expansion of national parks and restoration efforts.

Throughout, the binding contract Janzen negotiated with the Costa Rican government and citrus producers to supply citrus mulch to the national park restoration effort remained in effect.² How could the citrus producers escape

this and maximize profits while the US felt the shortfall of citrus products? The citrus producers lobbied the Costa Rican legislature, which produced a bill outlawing dumping biological materials, including agricultural 'waste' on federal lands. The contract was nullified and the citrus producers were free to use castoff rind from juice production as they wished.

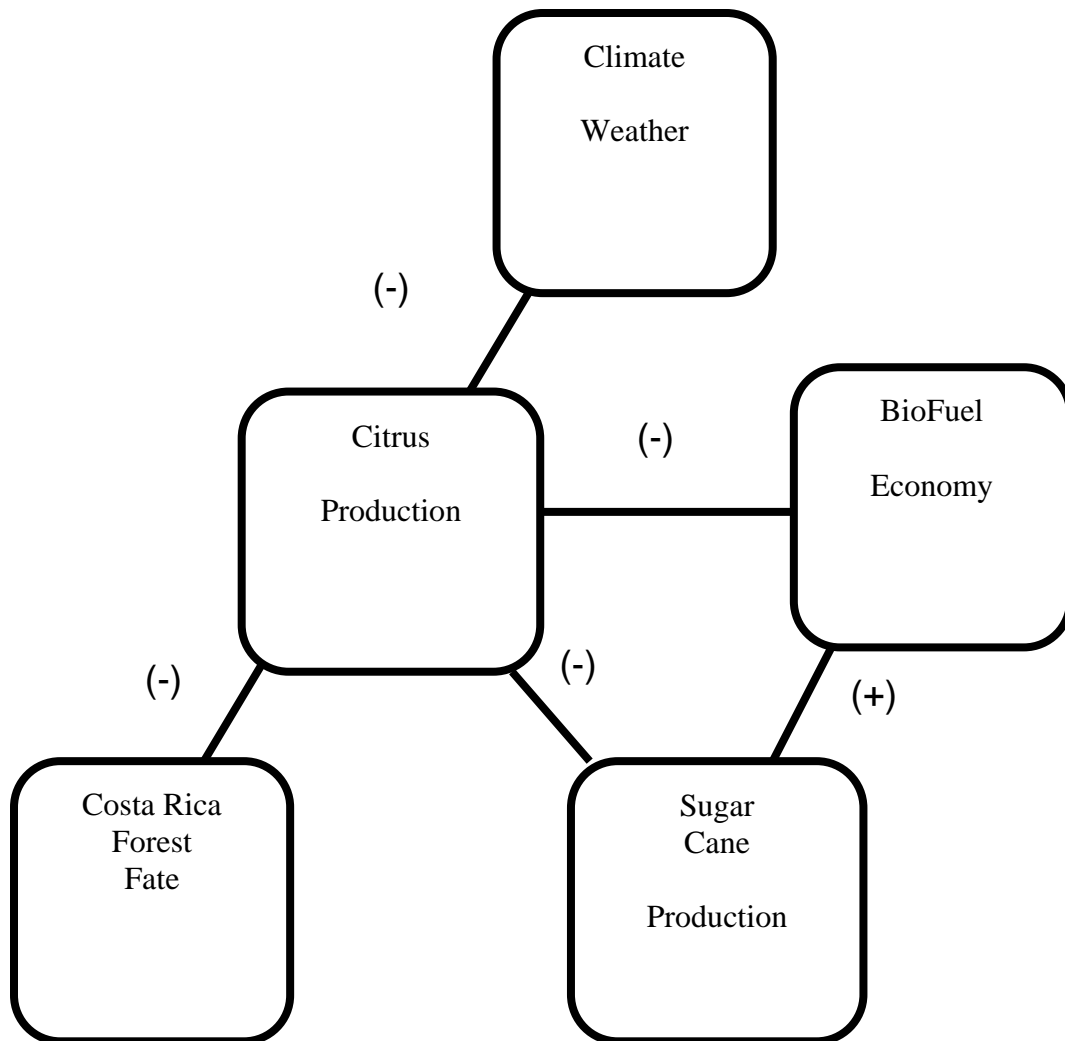
Janzen's project was an international collaboration which included scientists of several types from several countries, the citrus industry in Costa Rica, federal environmental agencies and international environmental groups. As such, it had a much broader base than most science collaborations, but then its goals included significant changes in land use and economics. In fact, Janzen's efforts helped convince Costa Rican government to set aside in natural preserves a greater proportion of its land area than has any other country, including the US. Over the past few decades, the economy of Costa Rica has shifted from agronomic to ecotourism as dominant features. Ecotourism is second only to electronic components produced by INTEL in bringing in foreign currency, and it earns more foreign exchange than the nation's former export staples, bananas and coffee, combined.⁸ Janzen's efforts in support of this move have gained him every significant award he could possibly win, and Costa Rica has become a model of transition to environment-friendly economies.³

The complexity of this situation is nothing short of astounding. What

started as a promising application of a basic research discovery – the impact of orange rind (citrus chemistry) on plant growth and its use in habitat restoration – was sideswiped by global economic, climatic, and ecological factors no field biologist was likely to consider in planning an international research project. Janzen has long been well-connected with the Costa Rican government. He even established a federal biodiversity agency in Costa Rica. But the impact of weather on North American crops, the global demand for biofuels, and the profitability of environmentally-sound products never entered into his research plans. In the end, Janzen remarked, what he really lacked was good lawyers to deal with industry and legislative maneuvering.

A systems perspective

The citrus peel/ecology/economics story can be represented as a box-and-arrow model. Such a picture would depict the major factors and their interactions. Climate influences weather (hurricanes), which influences citrus production and crop value; middle class growth in India and China plus dwindling reserves and political unrest influence fuel prices, which influence biofuel production, etc. The resulting picture, a complex set of lines connecting boxes, is easy to imagine. A group of events, forces or elements that can be connected by interactions in this way is what we call a system. An ultrasimplified version of the Janzen problem would be:



Box-and-line network models are common depictions of all sorts of systems ranging from electronic grids to ecological communities to human social systems. An entire science, systems science, has developed to the point that there are entire departments focused on quantifying and understanding how different sorts of connections relate to each other.⁹ A very important trait of interactions in complex systems is that the outcomes, products, eventual states, of a system are not evident from merely examining the participants. Complex systems have ‘emergent properties’, or

behaviors not predictable by examining individual elements.^{9, 10} Ecologists have long appreciated that the natural world is a complex system comprised of many complex systems, and the concept of emergent properties has guided ecosystem science for many years. In fact, Daniel Janzen’s scientific career has produced one spectacular example after another of complex interactions among species. Many of his, and similar discoveries by others, have come about by collaborating across disciplines; it takes multiple perspectives and approaches to unravel complex interactions.¹⁰

With the flattening of the earth, our perspectives on systems are changing. Since virtually no place on the earth can be said to be uninfluenced by humans, human activities are increasingly seen as part of ecological systems.¹¹ The impact of humans on complex ecological systems can now span the globe in a very short period of time. Species are transported around the world and introduced to new systems at will, or more typically by accident, transforming the systems receiving them. We can now alter species in ways and to an extent never seen before, with largely unknown consequences on complex interactions we really don't understand yet.¹¹

With humans in the mix, concatenated systems outside nature enter into the picture. As we see in the orange peel example, humans added complex economic and social systems to the factors influencing the future of the tropical ecosystem Janzen is trying to restore. Entire disciplines exist to understand those human systems. Add global weather patterns (hurricane impacts), a notoriously complex and difficult system to decipher, and their socioeconomic impacts, and it is clear that Janzen would need a vastly expanded corps of collaborators from disciplines that usually don't interact (climatology, economics, law), working with international - global - systems to ensure that he could predict the outcome of his efforts and the future of the northwest Costa Rican forest.

The research university's role

There is only one sort of organization where the disparate disciplines needed to unravel the emergent properties of complex systems commonly co-occur: the

research university. But despite considerable rhetoric and a mandate to integrate (particularly for land grant universities), universities and their administrations have not been very successful in making the most of this opportunity.¹² Individual researchers are still rewarded primarily for individual, not team, efforts. Highly visible, successful faculty are not encouraged to develop interactions with and skills in junior colleagues. Collaborative opportunities are missed more than made because of a lack of communication and intellectual isolation, especially on larger campuses.

Given the difficulty in developing interdisciplinary collaborations within a campus, the problem of integrating the disparate interests and far-flung connections needed for international collaborations is truly daunting. Institutional culture leaves it to the individual researcher to solve these problems, but this engenders a real opportunity cost. The typical successful researcher has an eye for funding opportunities. Justifications for funding particular kinds of research come and go, and sometimes researchers are tempted to see a new trend as a way to fund a new or even existing line of research. Of course, that research must in some way serve the needs of the funding agency, but some ongoing work can often be rolled into such a body of work, even if it's not quite on the same target. For example, current interest in biofuel development is generating a funding stream that attracts the attention of university researchers in many fields. As the orange peel story illustrates and many have documented, the net value of investing in biofuels remains uncertain,

and depends strongly on global economies of two types: monetary and carbon. If time, money and careers are to be well spent on such projects, a global systems perspective is absolutely essential. A productive scientific career can be wasted by hitching one's funding to a post whose reliability and utility can be influenced dramatically by such diverse and distant factors as climate change, economic trends, a focus on 'green' technology, etc. Those factors reach around the globe to influence the utility and future success of individual research projects, and the successful investigator must realize that, even when the research focus seems local and narrow. Nothing is local or narrow any more.

All research programs are increasingly international research programs, whether the researcher goes abroad or not. Yet training, at least in the sciences, continues to focus on what happens in one's field, on one's campus, in one's lab or office. Researchers who do go abroad are challenged to decipher unexpected factors ranging from minor annoyances to major interference. Researchers accustomed to controlled experimentation eventually learn that nothing is totally controlled. The best way to deal with this is to imbed one's research in the systems context appropriate to it and work with collaborators whose expertise is in the other elements of the larger system. As Janzen learned, a habitat restoration project based on a narrow biological finding can be influenced – even halted – by global factors ranging from weather to politics. What is needed for a project like that is a collaborative team with

economists and lawyers who are as qualified as the biologists.

Universities trying to internationalize their student bodies provide resources that inform students about the factors that will influence them abroad. Research universities should be able to provide similar information to researchers to handle the minor annoyance part of the system in which they will work. But what about the major factors that produce unforeseen outcomes? Universities cannot characterize the particular global systems in which each researcher might work. However, it is possible to learn about and call attention to larger trends and issues likely to influence international research outcomes. For example, plant scientists in the Bond Life Science Center at the University of Missouri are interested in developing biofuels from corn and soybeans. As part of their closest administrative relationship, the Center Director asks hard questions about the global impacts of and impacts on their research. Will this research have a salutary impact on the global carbon budget? Do economic trends indicate that there is a future to what they wish to develop? If they are going to work in international teams, are there cultural, social or legal factors that may negate their progress (e.g., an unwillingness to deal with genetically modified organisms)? The exercise of asking questions at the system level forces the investigator to consider specifics, and can be useful even if the systems analyst is not intimate with the research.

The ability to keep abreast of global, international developments and ask

researchers questions that may steer or focus their decisions could be done by administrators who can stay in contact with such information. On most campuses, administration of international programs is done at a level quite removed from these issues, by people who are not or maybe never were engaged in international problem-solving. Frankly, my experience with some foreign-study offices suggests that they might not have much experience with foreign study. An officer or entire staff whose job it is to help researchers become aware of global issues when developing research projects would be invaluable, and could contribute greatly to the “global land grant” university’s mission.¹²(Foster, this volume) This goal could also be accomplished by generating broader collaborations, for example among faculty in science units and those in relevant liberal arts units with international, global interests. I suspect that it may be easier to devise a staff devoted to placing research ideas in a global context, perhaps as part of the grant proposal preparation process.

Paying attention to complex systems and developing quantitative models predicting their behavior is now a well established academic discipline. Systems scientists are interested in all sorts of systems; it’s system organization, not the identity of the elements that form the underlying focus of study.⁹ We need to promote the application of this discipline to the formation of interdisciplinary, international collaborations and coalitions. For that matter, universities would certainly benefit from systems analysis of themselves.¹³ A university agency

staffed by “applied systems scientists” whose job it is to place research projects in the larger context to which they belong would be an invaluable resource and could be necessary for many institutions to achieve their goals. The concept of an “Office of International Programs” needs dramatic expansion in concept and application.

Conclusions

Forming international research programs is one example of a larger problem in university-based research: a failure to appreciate the complex contexts in which projects are imbedded. The complexity arises from natural, social, economic and other causes, and includes elements that range from minor annoyances to major roadblocks. Globalization is a reality at many levels, so that almost no research project is truly isolated from complex systems that may span the globe. Because academics are trained to focus narrowly and develop their research in a domestic setting, they would benefit from an agency whose role is to suggest or even outline the complexity of the system in which their research will be carried out. Because systems science is “taxon-free” (the identities of the elements are not as important as their relationships) a system scientist can make a significant contribution to individual projects without be expert in the research proposed. Universities should consider systems analysis a critical element in the academic administration system, since the benefits range from enhancing their own effectiveness to their global impact.

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