Right Scale, Resilient Watersheds: Managing Complexity through Nodal Networks

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What does the group of Wall Street traders focused on banks of computer screens have in common with the watershed communities of South America's Gran Chaco, the second largest ecosystem on the continent; the priests of Bali, where some of the earliest evidence of irrigation used in rice cultivation is found; the Arctic Circle's indigenous communities of herders and hunters; and National Heritage Areas? A great deal.

They all (1) evaluate information in much the same ways (scale, timeliness, credibility, action, risk, and uncertainty); (2) act both tactically and within a large-scale vision; and (3) serve others outside their own group.

However, the Bali, Arctic, and Gran Chaco groups go further in considering the outcomes of their management practices because any mistake they make will have direct consequences for their individual lives and for the lives of their communities.

Bali's large-scale rice production system has produced high yields with low inputs for nearly 1,000 years. The Arctic indigenous peoples' resource management system has operated sustainably for countless centuries. In the Gran Chaco, the rivers' shifts have fostered complex, cooperative behaviors that are organized to benefit multiple communities.

In contrast, traders in the global financial system—another large-scale, complex system—have crashed routinely with devastating consequences for both themselves and far too many of those served. The transferable management lessons learned from the Gran Chaco, Bali, and the Arctic could be highly consequential for global financial markets. Fundamental survival can be a great motivator when developing superior life-support systems. It is here that indigenous peoples excel. They use shared values.

Let's explore. In the Gran Chaco, the Guarani and others see great value in social network systems that link the energy of diverse people and cultures across landscapes.[1] Their management methods are continuous observation and data exchange, and are often embodied in "case studies" featuring principals like Fox Walker. Fox Walker is a survivalist who shifts shape as readily as any serious investor in a turbulent market.

Who walks like the Fox? According to the Guarani

peoples of the Gran Chaco's Parapeti and Pilcomayo River basins, he is an ideal manager and culture hero because he is astute, intelligent, and stalked by danger but never conquered. His principal scene of action is the present world; his role is that of a survivalist adapting to the moment, capable of reading and writing, riding horses, hunting birds, stalking the jaguar, and using GPS. He is a radical transformer, rule breaker, and commander of frontiers. He fractures norms and patterns while simultaneously reinforcing them. Sometimes, if need be, the Fox is an audacious liar. He bridges time and space in ways that evoke risk and uncertainty. He is a clever adaptive manager.

The Fox of today is fulfilling his role as ideal manager and cunning survivalist by trying to maintain the Parapeti ecosystem's state of equilibrium. When adapting to new towns, outside developers, investors, or new settlers and their alien ways, he does not lose his identity but goes forward like the unbounded and smart rule breaker and maker that he is. One can see Fox Walker both successfully running the rapids of the winding, shifting, elusive rivers of the Gran Chaco and Bali, and coursing through the channels of Wall Street.

What follows is management advice from the Gran Chaco, Bali, and the Arctic, where co-management of resources based on right scale and widely shared systems of thinking and acting—if pursued—benefit both the wily and the wise.

SCALE: RIGHT SCALE

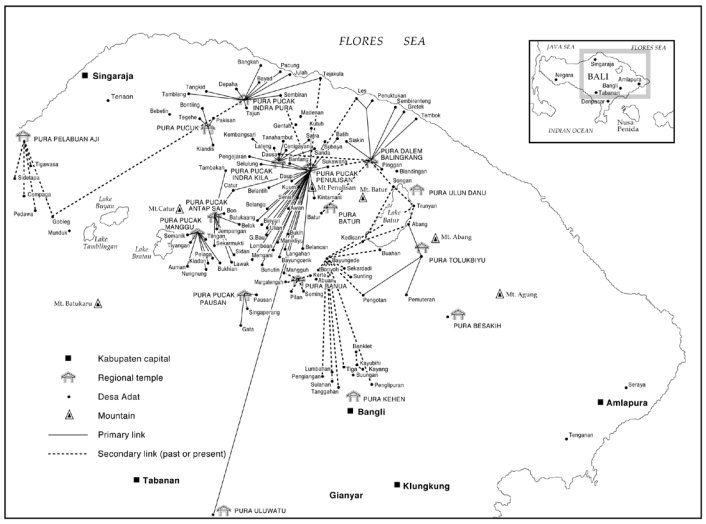
Successful natural-systems management means operating at right scale, where the best boundaries are defined by direct observation, rapid networked information exchange, flexibility in response, and transparency among all agents. Often this equates with recognizing and operating within natural-systems boundaries such as watersheds, mountainsides, and high plains areas.

This type of management, recently named *network governance*, is done highly effectively in Bali, in the Arctic, and with growing ability in the Gran Chaco. It can be observed in the success of National Heritage Areas in the United States as well. It relies on a set of operating nodes located within the boundaries of natural systems that bring together for comparison the latest information from highly experienced observers, time-tested evaluators, and open forums with an acute willingness to solve the problem in the most respectful way possible. This does not eliminate conflict but does make it much less severe. Analyses of incoming real-time data are assessed against historical empirical knowledge of the river systems' behaviors in regularly scheduled and highly nuanced dialogues.

According to Innes and Booher, there are four key aspects of network governance:[2]

1. Reciprocity: sustained collaboration results from collective dialogue, in which the relationships themselves are the incentive to act in concert with others.
2. Collaborative not competitive behavior: the relationships aid multifaceted problem definition.
3. Opportunities for learning: relationships with actors in multiple sectors result throughout the system unlike in a more controlled, hierarchical top-down approach.
4. Creativity and flexibility: networked local governance encourages information richness, especially when managing complex natural systems like watersheds.

Let's look more closely at some examples of right-scale resource management using network governance nodes. On an island of 5,633 square kilometers, the Balinese have constructed a dense and redundant network of "managing" temples that are strategically placed at each level and node of the watersheds' complex irrigation systems. These have provided farmers with an information platform on which to coordinate three key variables: cropping patterns, water flows, and pest management. Farmers are organized into *subaks*, Balinese farmers' associations, with leaders who represent them at the temple. This compares to the Gran Chaco knowledge-network systems across the 261,000 square kilometers of Pilcomayo and Parapeti River basins in southern Bolivia and northern



Argentina. Currently, the mix of outside, inside, local, and global knowledge about these vast river systems remains uncoordinated and therefore impossible to use in the same way that both the Balinese farmer/priests with their rice output and Wall Street traders with their revenue generation do to maximize their efforts.

This nodal coordination in Bali has been accomplished by leaders who form a core of managers who are embedded in temples and who have acted as scale-free nodal points since the eleventh century. At the temples, collaboration and negotiation are disciplined and routine, consolidating results of regular meetings of subak farmers, which represent the filtering of detailed direct observation. The planning process finds subak heads meeting once a year to decide on a highly changeable yet coherent cropping pattern—adaptive planning at its best.

There was and is no central control of this Balinese system. It is not dictatorial, linear, or hierarchical. Each subak and temple manages its own irrigation works, taxation, and labor force with intensive communication among the networked actors. This institutional arrangement of farmers' water temples facilitates coordination and yet needs no formal enforcement power (such as the threat of force or ostracism) or strong central authority. Each cooperating farmer has maximum yield as an incentive to seek and therefore to follow whatever advice and feedback is collectively determined; however, the temple system's tight cooperative relationships does not mean that it functions as a free-market system.[3]

In the vast ecosystem that is the Gran Chaco, this type of intricate understanding of shared resources and watershed management is just emerging. There, local peoples realize that it is their active participation in gathering and sharing information among themselves and with the public and government that will help ensure their long-term control of the river system they rely on for life and livelihood. For example, in addition to their environmental indicator monitoring work, a ninety percent participation level in gathering socioeconomic data in the Upper Parapeti has helped to make the population's livelihood patterns and their dependence on the natural river and forest more comprehensible to the government and others.[4]

Similar to Bali's farmers, Gran Chaco's indigenous peoples are intimately connected to the river's behavior. For example, as soon as the seasonally dry riverbed fills with water, the leaders of river communities meet to determine how principal irrigation canals will be cleaned. These meetings are particularly important for the Isoso tributary because they involve families of Upper and Lower Isoso and thereby celebrate the community's enjoyment of life together, while they also remind everyone of the rules, oppositions, and shared origins of the Isoso, which unite them.[5]

The local NGO Yangareko has nurtured nodal relations between the flat territory downriver in indigenous Isoso and the upriver territory of rural farming communities in the sharply dissected Andean foothills, where the Parapeti begins its journey. Upriver, Yangareko shared technical information and assisted in organizing communities to consolidate their own local watershed committees. This NGO is now working with those local civil society committees and the fourteen local governments (counties) with jurisdictions along the Parapeti to form the Parapeti Watershed Management Group that will share local information and encourage management up and down river. This cooperation will ensure that this valuable local resource continues to be available to everyone living along the river. The details of collaboration across the fourteen counties are being explored through discussions among the parties as they adapt to the changing policy environment in Bolivia.

The ongoing professional assistance of small NGOs like Yangareko is producing small networked systems of rural people whose confidence in assessing and communicating local conditions to governmental decision makers and outside investors is beginning to act to prevent further impoverishment and other threats to biodiversity in Bolivia and Argentina. The small local NGOs that are learning from each other include Yangareko, AgroXXI, Fundación para la Gestión

e Investigación Regional (FUNGIR), Gran Chaco, and Proteger. (For more information, see http://www.cuencadelplata-granchaco.org/.) Similar collaboration between small NGOs and peoples' citizen associations grounded with local roots can be found in Nepal, India, Indonesia, Peru, Colombia, Mexico, Kenya, Tanzania, Ethiopia, Namibia, Cameroon, and other countries. However, unlike large international NGOs that actively seek publicity, these smaller NGOs tend to operate beneath the radar. While limited and in need of replication at key water-management points, these ad hoc successes have created a starting point from which to create a wider network of linked management nodes that could transform river basin management in the magnificent Gran Chaco ecosystem.

TIMELINESS: DIRECT OBSERVATION AND RAPID RESPONSE

The intricate management systems highlighted in the last section show relationships that are intelligent and have evolved to work to the best interest of those operating within natural-systems boundaries. Rates of response to observed changes are rapid, and, as with the fabled Japanese quality assurance approach, incontrovertible change is immediately shared for wider understanding and application. This same pattern of rapid response and action also characterizes trading operations around the world.

For the past seven years, indigenous observations from a timely, sophisticated, and comprehensive river-monitoring system composed of more than sixty local monitors in the Gran Chaco have been consistently entered into a GIS system and overlaid on to satellite imagery of the Pilcomayo River during different flood stages. This enables highly accurate and well-timed updates to the GIS ecosystem model, which is used to project flooding patterns from the Pilcomayo River tributary network. The Gran Chaco's communities call on more recent technological tools and partners available through FUNGIR, which serves as the articulator, assisting in interpretation and projection of future scenarios.

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These local managers are also joined by people working for the national weather services of Argentina, Bolivia, and Paraguay; the Trinational Commission of Pilcomayo; the Argentine and Brazilian Space Agencies; United States Geological Survey and National Aeronautics and Space Administration; and the Formosan provincial water authority. This creates a new scale, expanded both horizontally and vertically, that, in a sense, models the smaller nodal network seen in Bali.

This type of highly effective use of network systems and governance is also employed by many Arctic indigenous peoples. Constant observation of landscape, animal movement, and plant appearances are embedded in routine conversations that culminate in timely major regional decisions made at routine larger gatherings. These occur at least once a year and, depending on urgency, up to four times a year. At the same time, meetings with representatives from international institutions, national agencies, and other groups have been systematically undertaken, incorporating the advice and observations from the Arctic indigenous peoples' traditional systems into outside bodies. Attentive and astute explanations are filtered through a local lens for relevance before being passed on.

It is difficult to deny the similarities to the Wall Street traders who are engaged in constant, intensive monitoring across a variety of inputs, using sophisticated evaluation systems, and relying on information from a host of outside sources. But the highly contextual, nuanced changes in localized settings are simply not available for review and analysis. Even adding data from local market monitors can be in error when compared with farmers' directly observed and intense experiences.

CREDIBILITY: TOOLS AND TRUST

In recent times, the resilience and strength of the ancient Balinese system has been demonstrated twice: once, when the Dutch attempted to combine the originally separate irrigation and taxation systems, resulting in conflict and reduced revenues, and, most recently, with the Green Revolution's forced program of prescriptive rice varieties and chemical inputs, rather than reliance on the time-tested intrinsic value of farmers' network governance.

Any top-down control—whether from the inside or the outside—has not improved on the Balinese system of rice production. This was the case with both Dutch colonial bureaucratic controls and the green revolution's imposition of untried, outside seed varietals. Long-term farmer "testing" and proven indigenous

system that resulted in the flexible, multi-scale food security system allowed a nuanced understanding of the intricate interplay of water flows and pest management—the two key elements affecting sustained high yields.

The wave of European colonization in the nineteenth century urbanized land and commercialized production of several Balinese cash crops including rice, tea, and opium. Because rice was a large source of government income, the Dutch were moved to try to improve the flexible Balinese system by imposing their own comparatively rigid bureaucracy on the management of water, rice, and taxation. This simpleminded imposition of an outside system of irrigation did not recognize the complexity of the sociobiophysical systems of rice production.

The rice production system destabilized when the Dutch colonials mismanaged the overlay of irrigation and taxation networks. Under the outside Dutch authority, village heads had nominal authority over both irrigation and agriculture, and collected agricultural taxes through the temple system. But since ancient times, the irrigation systems and water temple networks typically extended beyond the boundaries of village administrative units and were a much more accurate measure of total water availability. This mismatch of water, rice, and taxes created a great deal of conflict and was corrected only when the brief colonial era ended, at which time village heads lost any administrative role in irrigation and became responsible solely for collecting taxes.

This institutional framework allowed the Dutch to transform rice into a cash crop and begin exportation. When Bali gained its independence in 1950, the country continued on a path toward development based on the bureaucratic capitalism of their colonizers and did not return to the decentralized ways of the precolonial era. Consequently, the irrigation bureaucracy that altered traditional Balinese society provided an accommodating framework within which the Green Revolution could operate.

Paralleling what the Dutch had attempted many years earlier, the Green Revolution was an attempt to convert rice from a subsistent crop into a cash crop. However, the engineers of the colonial age had little technology to offer, whereas the Green Revolution offered new agricultural technology such as chemical fertilizers, pesticides, and new breeds of "miracle rice" in a fifty-four-million-dollar modernization scheme for Balinese water temples. This large-scale development project began at the International Rice Research Institute in the Philippines and was implemented in Indonesia in 1967. The program, known as Massive Guidance, furnished new agronomic practices to farmers.[6] In Bali, the Bali Irrigation Project was launched in 1979 by the Asian Development Bank in order to improve the performance of irrigation systems while disregarding the practical oversight and coordination role of water temples.[7] J. Stephen Lansing writes:

> The Green Revolution approach assumed that all agricultural information was purely technical and that production would be optimized if everyone planted high-yielding varieties of rice as often as they could. In contrast, Balinese temple priests and farmers argued that the water temples were necessary to coordinate cropping patterns so that there would be enough irrigation water for everyone and to reduce pests by coordinating fallow periods.[8]

The bureaucratic procedures that changed irrigation patterns and cropping cycles undermined the water temple system of Bali, which led to the demise of this outside, top-down program. While the first few years brought greater harvests, Massive Guidance quickly led farmers' rice production into ecological collapse. The lack of crop rotation and natural planting cycles resulted in less productive fields and the use of chemicals and pesticides backfired as the insects that controlled infestation of the brown plant hopper were killed and hundreds of acres of rice crop were lost.

Besides this agricultural destruction, there were sociocultural consequences of the exclusion of the water temple system as managing agent. The temples' inherent social organization, which combines farmers, priests, village heads, and others, actively maintains

rice terrace ecology. Sustained high rice yields are final proof of the temples as nodes that synchronize the productive activities of very large numbers of farmers.

It was this combined force of people from the water temple nodal network who convinced the Balinese government that their subak system was superior to the management system of the Green Revolution. Not only did the outside system reduce yields, it also increased costs to farmers by requiring repeat purchase of hybrid rice, pesticides, and fertilizers, along with new machinery. Two additional dire outcomes were a loss of self-generating seeds, whose genetic material cannot be replaced once lost, and the loss of wildlife in the paddies, which is a good indication of soil decline. Finally, using specialized hybrids means breeders are faced with constant replacement as long-term production declines; this has been documented in all Green Revolution sites around the world.[9]

In South America, the peoples of the Gran Chaco are now rapidly moving toward interlinked management of their river systems. The Gran Chaco peoples have both practical and technically documented experience with their shifting rivers. This experience takes into account the difficulty of fully controlling both the topography and changeable water flows, as well as the annual flooding that enables fish migration upriver and dumps silt downstream as the water spreads out on to the plains to create valuable wetlands where fish grow to maturity. The people's flexibility in responding to movable landscapes has been nurtured by their unique resilience to flood and drought conditions. Once again, as in Bali, this fluid shifting is done with little cost to either regional trade or local economies. Like Fox Walker, the peoples of the Gran Chaco are survivalists who shift shape as the rivers' waters require.

Going beyond those in Bali, these indigenous peoples have at their command high-tech reporting tools, as well as more traditional methods of reporting. In addition to GIS and satellite systems, they have zoning plans and maps; analyses of vegetation, hydrology, soils, topography, and climate data; and socioeconomic data gathered at the household and community levels. This kind of detailed demographic information is gathered directly from families, then discussed by the community, and then shared with the government; without the families' efforts it would not be available. But unlike the case in Bali, the resulting guidance is not imposed through an outsider's massive guidance program; this citizen-generated information has been used in discussions with the national government on forest policy and in land-use definitions with the Argentine Supreme Court.

As a result, not only do we have credible, technically based recommendations to clearly show the kinds of impacts possible, but these are often projectable system-wide in the newly shared language of indigenous communities, local landowners, and global development and technical professionals.

Like the priests of the Balinese temple system, NGOs in the Gran Chaco "accompany" local communities and governments as they make decisions but do not act as executors of the projects; instead, they act as distant advisers, encouraging communities' continuous learning, as well as providing on-demand technical backup for their decisions. This skillful approach ensures that local peoples' keen observations and insights are recorded as perceived by them and not in an outside and, perhaps, less nuanced way.

In 2003, FUNGIR began acting as a critical node by training local environmental monitors who were networked to each other and able to engage the government, while at the same time assisting local communities improve their livelihoods and enabling them to access assistance for ecologically appropriate development activities. For example, socioeconomic information gathered by monitors in Salta province was useful to the Lhaka Honat indigenous organization and the *criollo* ranchers' organization in their territorial negotiations with the Salta provincial government. These negotiations were facilitated by the Inter-American Commission on Human Rights intervention with Lhaka Honat and the Argentine government. By acting on a stepped-up scale but still at the local level, more conceptual decisions emerge. Divorced from the fine observations of natural resource fluctuations and *not* affecting individuals, this neutral but grounded process lowers the noise level of high data input. Essentially, the years of experience offer a filtering node to make effective and fast decisions.

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This type of decision making for natural resource management does have its downside. As we are seeing with the melt of permafrost across the Arctic Circle,

radically new land and water changes can disrupt food production and migratory patterns. Massive blocks of ice that thrust up to the surface are destroying houses and pasture lands. New freeze patterns are making it difficult for grazing animals to get food. Local people can no longer rely on past observations of weather or plant and animal appearances to guide their planting and harvesting cycle. Where these problems arise, new technologies and outside information can help with adaptation.

The Gran Chaco also experiences this type of new dysfunction, except that there the evolved resilient behavior is in peril because of infrastructure development and loan projects that have not taken into account issues like the costs or benefits of highly productive established algarrobo groves. Algarrobo are very deep-rooted trees that provide household fuel and high-protein seeds, as well as shade for useful understory plants. Reliance on local communities' highly detailed and credible data on river management has been overridden by incentives from agro-industry project funding and by loans that continue to proceed on the basis of the lender-government relations and external advisors' assessments in regions where local people have long occupied lands that are officially classified as *fiscal lands*. Local people do not have land tenure rights; this leaves them vulnerable to resettlement if the government encourages outside investors to buy fiscal lands for investment. One thinks of the Balinese government's recognition and trust in its own farmers' customary rights and rice production methods that reversed the impact of a forced agricultural system from outside the country. This recognition is even more important in the Gran Chaco, because even with the careful balancing of natural local resources, high poverty levels and a tenuous subsistence economy prevails in these intricate and idiosyncratic river systems. This combination of naturally tenuous landscapes, maintained with low disturbance of natural forest but without strong tenurial security, makes these wild river ecosystems even more vulnerable to outside forces that can exploit the lack of public information for their own interests.

It is up to the nations and regions sharing the rivers of the Gran Chaco to listen to the nodes of local people who live upriver and downriver along the rivers' courses and who understand the intricacies of the watershed's management in order to temper and wisely apply the benefits of outside intervention and right-scale network governance. Enabling more NGO-local organization nodal networks is a critical step in the right direction. Creating more nuanced local-level understanding can help prevent incremental loss—something long recognized as perilous to land change and biodiversity loss. We have proof of this from 2,000 years of successful nodal systems management in Bali. This system of information management is replicable throughout the world.

Whether or not this could work for the global capital management system's impact on natural resource utilization is questionable. Traders at their computer terminals are caught short when manipulating critical phases of resource management because of long supply chains that begin with local resource extraction or industrial farms and then move through diverse and often energy-intensive production processes to global consumption. The end result is mostly a blind management process at the top. Capturing true cost in this system is probably close to impossible, and trading futures contracts becomes riskier than it should be. Despite remarkable computer-based tools, recurring market crashes have generated little trust. It is the position of this paper that crashes of systems (ecological or financial) result from the multiple incidences of actions that individually might not cause harm, and are not necessarily monetized, but that carry severe financial and ecological impact when combined without deliberation over feedback among nodes as these decisions are made. Unlike mortgages, the unique and beneficial indigenous peoples' knowledge trade exchanges are highly nuanced, place-based, and not always comparable; they cannot be bundled for even regional-level trade. This alone may be a significant advantage in maintaining a stable, large-scale trading system.

ACTION: PROMPT AND EFFECTIVE

One of the most distinctive features of Balinese watershed management is the vibrant exchange among watershed farmers that drives prompt action on highly efficient flows and allocations to farmers; this is often accomplished through small volume releases. Pest outbreaks are quickly reported and immediate action taken to restrain their spread. Any farmer at any time has access to the nodal temple system, where with the aid of a "priest," reports can be logged and disseminated to those who need to know, whether to farmers in adjacent fields or those controlling downstream flows.

In Bali, the construction of boundary-crossing water channels and tunnels provided an impetus for

the development of irrigation societies that are largely autonomous from other social institutions.[10] This has created a double-scaled local management system that operates as a feedback loop to control the risk of crop loss. Videotaped records of monthly inter-subak meetings show the lively discussion of key issues. For example, we find that the perceived threat of pest invasion is strongly related to the willingness of the heads of upstream subaks to synchronize cropping. In years of high pest damage, more synchronization is observed, while in years of light rains, less cooperation happens.[11]

This high information flow among farmers and subaks sustains high-yield harvests, which are achieved by the subaks' coordination of irrigation and cropping schedules to reduce losses from pest infestations or to mitigate watershed-wide water shortages. These societies are just one level up from individual farmers. Importantly, the subaks are still highly accessible to the farmers so that the small, incremental losses that might go unnoticed and untreated in a thinner or less extended observational system do not occur because they are seen by those who are highly motivated to fix them.

Resilience is further enhanced in this watershed-management system by exempting some water sources from irrigation society control, which deals only with the flow in major canals. Because of the length, complexity, and fragility of Bali's canals, downstream subaks suffer losses from percolation and evaporation. Consequently, it is difficult to control the real supply needed for downstream subaks. Therefore, downstream subaks routinely take advantage of the excess flows from upstream neighbors and local springs and seeps. These small-scale water sources are vital for most downstream subaks to make up the deficit caused by percolation and seepage losses in the canals. In effect, they are localized buffers against short-term shortages. They are not always needed but are there as backup and used at the discretion and for the need of individual farmers. They are good for densely populated, intensively cropped, and biologically diverse systems.

In the Gran Chaco, the progressive movement toward systemic watershed management has just begun with the identification of responsible "agents" who produce highly relevant scientific and socioeconomic data. These agents are comparable to Bali's subak managers and engage with people's cultural self-definition; they are bound together by a shared narrative, such as that of Fox Walker. The combined thrust of readily shared and understood data and key agents throughout the watershed is a first step toward establishing a key nodal system. An important difference is that the information is generated through new technologies and promoted by means of videos, photos, and participatory theater. These visual aids serve to build and transmit not only numerical data but also the more pungent and visceral historical memories of the people themselves, while strengthening the local watershed associations and binding communities together.

This use of information is highly promising for building complex and responsive watershed management for the Gran Chaco rivers by making the entire system more resilient and less vulnerable to outside interference. But until governments within the river system cooperate to achieve a much deeper knowledge of the Gran Chaco's ecology and respect for indigenous peoples' intimate understanding of the shifting river, long-term health and well-being of this second largest ecosystem in South America will be increasingly at risk. Successful adaptation and the new understandings that are taking root will be eroded by outside forces—both economic and through new agro-industrial expansion. These already have increased poverty, sometimes to a severe extent, in the indigenous and rural communities.

Unlike the Gran Chacoans and Balinese, Wall Street traders frequently have no knowledge of how their trading actions affect on-the-ground resources. Despite immediate dataflow changes at their fingertips that report daily and often critical changes to territories affected by local weather, water availability, disease, and population shifts, without recourse to comparison and negotiation among widespread local agents dealing in the same commodities and financial products, these traders are blind. And it is here that farmers' management systems, expertise, and experience make them the superior players. They both reduce risk of failure and incorporate tested, short-term adaptive responses.

Traders' risk of mistakes is heightened by their inability to operate as full-scale, planetary coordinating agents with the ability to correct novel mistakes. Instead, errors of any size escalate rapidly, making corrective interventions nearly impossible. We've seen what a small human error can do when cascading through a planet-sized trading network, sweeping through the global financial organism, slowing it, and,

increasingly, at times choking it to a halt. The cost of repair can be significant and sometimes includes significantly reduced rewards for those doing the trading. It is arguable whether the present group of traders is equipped to view and respond to the relatively small and vital changes to the many diverse natural resources reported on their screens. As with any information system delivering large-scale, globally aggregated numbers, the observed but frequently uncounted losses at the local level aren't detected until they reach a critical accumulation. No algorithm to date can analyze the many tiny changes inherent in intricate planetary systems.

RISK AND UNCERTAINTY: STABLE LIVES

By the mid-1980s, the highly desirable ecological impacts of Bali's water temple system—misperceived in official reports of the time as a "rice cult"—were slowly recognized by government officials. This stable, double-tiered local system with its persistent balancing of water, rice variety, and coordinated planting to manage pests contrasts sharply with the uncertain rice production of the Green Revolution's modern methodology. Once farmers reinstituted temple-based coordination, despite resistance from outside consultants and those officials supporting the modernization program, risk of failure once again became manageable. In fact, the utility of a separate water-management system was recognized as early as the ninth century, when the term *water tunnelers* was found on a list of professionals whose labor and other costs were paid by those who expected to profit from the flow and who had no connection to the elite courts or village administrations. The breakdown of the long-stable Balinese ecosystem during the Green Revolution clearly showed that without farmers' constant monitoring and linked-temple node management, the crop losses (and ultimately lower aggregate output because of exploding pest populations) would have gone unreported. More critically, without this event's interpretation by local actors, it likely would have devolved into total system failure. This might be expected because the Balinese water temple networks have extended themselves throughout the watershed through many local initiatives and intermarriages that produce a kind of internal *budding process*. While even budding can destabilize from the bottom up, water temple agents intuitively know that a local budding process can present a potential challenge to the overall expansion of the rice irrigation system. Modeling has shown that repeated shocks to the system could potentially push it outside the parameter space where good rice harvests can be sustained, and poor harvests could make further expansion economically unviable.[12] In 2000 years of real life, this has never happened.

> "The lack of crop rotation and natural planting cycles resulted in less productive fields and the use of chemicals and pesticides backfired

This stability is in contrast to growth through elite sponsorships that operate off political or economic, not biogeophysical, mechanisms. The most destructive of these can be outside economic forces that often do not find corresponding partners at the local production level. Frequently they operate as opportunistic free agents to destabilize ecological and social systems. But it is the highly individualized and uniquely local "budding" that has reinforced the stable watershed landscape by acting as a risk-mitigation mechanism for the larger scale irrigation systems. It acts as a kind of safety net for the already well-synchronized common-pool management network. Only recently documented, it is this understanding of the resilience of the natural resource base of Bali's watershed that has made long-term, stable, low-risk rice production a reality.[13] Critically, the Balinese government now recognizes and supports the water temple network, which needs no herbicides or insecticides for pest control, and does not require continual repurchase of seed varieties that do not replicate. Such capacities allow this network to avoid numerous costs throughout the value chain.

As in Bali, the Gran Chaco ecosystem is under threat of destabilization from both regional and outside financial agents in the form of investment-driven development for roads, channels, and new soy production areas. The situation is also becoming more unpredictable in actions and timing because the rivers' behavior is affected by the annual cycle of rains that are changing due to climate change and because off take and channeling of the water downstream for irrigation and industry are affecting fish migrations moving upstream. People have traditionally adapted to these risks of unpredictability through livelihood strategies that mix hunting, fishing, gathering of algarrobo seeds, and farming—the dominant pattern before European conquest through 1960—and free-range live-

stock; cattle and goats were added in the 1800s. A new level of risk is being added by new titling programs that are being used to alienate lands from local knowledge-bearers for use by agro-industry. This increases the likelihood that the system could be flipped once the institutional elements that maintained resilience are removed.

Poor project design is also affecting fish migration and changing annual flood patterns. In short, the imposition of outside development will in the Gran Chaco, as in Bali, disrupt a complex, sustained natural waterway and impose potentially costly and destructive changes to food production and the health of all species. As in Bali, risk of famine is increased as indigenous forecasting models for food production must be changed and no new reliable production estimates are available. Additional ecological stress is incurred with the failure of naturally cleansing river services that slowed and mitigated pollution from upriver oil and mining extraction.

The increased stress is attributable in large part to imposing outside generic financial schemata on highly specific local trade and management systems. It would be more beneficial and productive to carefully tailor the generic financial schemata of outside agencies to reflect the unique and complex biogeophysical systems they hope to harness for widespread economic gain and to create a nodal management system similar to Bali's. For example, monitors from indigenous communities, funded by the European Union (EU) to identify critical sites that needed to be taken into account for planning future interventions along the Pilcomayo, demonstrated that the Gran Chaco indigenous peoples have better knowledge of the specific biogeophysical dynamics of the river than many of the technical specialists from hydrology offices. A key difference was that the indigenous monitors' proposals did not try to create generic and homogenized projects into which everyone would have to fit. At this point in their development, because of indigenous input, the resulting project proposals were based on highly specific, nuanced, local knowledge of biogeophysical systems behavior as well as the social particularities of different families in each community.

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However, this indigenous input and the resulting project proposals ultimately had little influence on the EU-sponsored Pilcomayo Trinational (Argentina, Bolivia, and Paraguay) Master Plan recommendations in 2007. It could be surmised that this resulted from EU specialists' ignorance of the Balinese experiences of imposed outside forces: the colonial Dutch watershed management interference and imposition of GMO-based rice cropping. In the Gran Chaco, local participation in the Master Plan was subverted by using approved workshop participant lists, and other tactics were used to narrow the perspectives of the participants. Importantly, these actions also critically narrowed the range of insights, outcomes, and management devices that the outside specialists needed to consider. This continues the tradition of failed donor-driven Pilcomayo Master Plans that began in the 1970s.

Significant and prolonged outside stresses impinging on a long-term resilient watershed can result in dangerous mismanagement when separate and new data elements and interrogative methods do not speak to one another. Lessons from resilience literature document the consequences of this failure to articulate at many levels and for biological, chemical, and geophysical systems. While the resilience lens offers up ways for both indigenous and outside systems to function together, it also brings cautionary lessons to bear.[14]

As we've seen in the above examples, water flows, fish reproduction and availability, and common-pool celebration sessions are all affected so that the socio-ecological system is being affected. And yet the ecological system still displays the capacity to both withstand shocks and surprises and to rebuild itself. In contrast, the Gran Chaco indigenous and local communities seem less able to withstand and recover from outside stresses, such as economic or political disruptions and their resulting impact on communities' food production. As Alcorn and colleagues have written elsewhere: "In the past decade, efforts in the Gran Chaco have been made to reconnect older governance structures and knowledge with the modern state apparatus. The national and provincial regulations and laws appear good in principle, but they are poorly implemented. The challenge is to develop a robust, cross-scale, institutional or network governance system."

LOCAL STABILITY EQUALS LONG-TERM RESILIENCE

In every case explored, social resilience—the abil-

ity of human communities to withstand and recover from stresses such as environmental change or social, economic, and political upheaval—has played a powerful role in maintaining a stable, healthy, and productive environment. It is resilient societies that uphold the space needed to broker novel human responses to change.

Again, Stephen Lansing offers a cogent example from Bali. There are factors in Bali that tend to enforce social resilience through subak cohesion, and indeed, survey evidence suggests that farmers believe that key economic outcomes are closely tied to those of fellow subak members. In particular, given the proximity and low mobility of individual farmers within a given subak, individuals have very long-term interactions with one another across a variety of social and economic realms, ranging from agriculture to marriage, in an environment where individual behavior is easily observed by others. In such a world, the long shadow of the future, multiple ties, and easily available information tend to promote very high levels of cooperation.[15]

The Gran Chaco communities, although in an earlier stage of regional evolution, also reflect this style of cooperation. The local leaders understand the watershed concept in relation to the wider geographic and cultural space implied by their upriver-downriver connections, and the interdependency of communities using the same resources. Discussions and exchange visits among indigenous peoples in these large-scale river systems have raised conversations about the respectful coexistence with others and have yielded knowledge of the cultural and economic diversity of everyone living in the watershed, as well as different perspectives on how to use and protect the environment. The small NGO Yangareko facilitated the signing of local agreements between different populations in the Parapeti watershed to demonstrate commitment to the overall well being of all the populations, and their good intentions to work together. FUNGIR, another small NGO, has also generated shared knowledge that has contributed to a nascent nodal network along the Pilcomayo. These activities also strengthened the local representative associations in each community to further enhance the network that already binds the communities together.

These many Gran Chaco community discussions are also important because they provide an occasion to reflect on the long-term impacts of land use. (This is something that can easily be overlooked in daily activities such as protection of both the water itself and the forested riverbanks to prevent silting and subsequent flooding.) These conversations renew knowledge and commitment to long-effective practices. Unlike with the EU process, along the Parapeti River, local knowledge-based documents have been developed with the communities' input. These documents have been printed and distributed to the fourteen county governments so that they now have a highly nuanced and thorough range of information available to them for land-use planning decisions at individual, community, and county levels. Moreover, the very existence of this documentation helps to protect the land. A very important role of the NGOs is constructing local ownership. They do this in part with the help of documentation by raising the profile of these local, ecologically sustainable land uses so that the provincial (Argentina), departmental (Bolivia), or national governments cannot readily claim that these lands are unused or unproductive and therefore available for others to introduce short-term, often destructive land uses.

These same long-term and large-scale information exchanges among local peoples are common in the Arctic. Whether through making traditional, regularized, annual rounds, attending annual gatherings, or sitting in meetings with representatives from international institutions, the goal of traditional natural resource management systems is to yield fruitful outcomes for coexistence. Major regional decisions continue to be made at larger gatherings that occur at least once a year and as needed—sometimes as often as three to four times a year.[16] The Arctic peoples of the studies consulted equate being knowledgeable with being experienced. Arctic indigenous leaders express this by

thinking of others' ideas and interpretations and envisioning (forecasting) outcomes when faced with immediate new problems or circumstances.[17] Once again, demonstrating the regularized capacity and practice of adaptive management.

The important stories of Yamozah (a mythical leader of Arctic peoples, who helped establish traditional laws and respectful relationships) and other key leaders tell how they listened to the concerns and problems of the people before providing a solution and action for the people to follow. And, if the problem was more widespread so that it affected other nations and indigenous communities, leaders listened to the situation, and the solutions taken by their neighboring nations.

As a final note, the United States National Heritage Areas (NHA), first established in 1996, exhibit many of the traits of resilient, indigenous resource management systems and function similarly to "collaborative complex adaptive networks"[18] or "complex adaptive systems." According to Booher, as with the river systems of Bali, these systems tend to be highly dynamic; they diffuse information across actors within the system, and they rely on some degree of randomness and probability between actors. These systems also continuously explore possible response options to opportunities or challenges and exhibit a constant interplay of top-down and bottom-up processes. Taken on their own, they form a new geography of shared information.

MORE ALIKE THAN DIFFERENT: IT TAKES AN OPEN MIND

Before going out in the Gran Chaco, the Fox dressed himself well—with new shoes, jeans, new watch, a stylish mobile phone, dark glasses—and converted into the "other." He is easy to recognize and admirable in how he walks. He navigates between two different worlds and reads the nuances of tiny changes in the complex ecological system in which he is immersed. In this sense, the Fox is like the traders who glide across their global screens to avert imbalances and appear on the scene arrayed in Gucci, Blackberry, and bespoke suits, calling up the arcane language of symbols that invoke the magic of markets, at times lost in the euphoria of herd psychology.

As Henry Huntington notes, the wealth of knowledge available from indigenous and local people can be locked in place by outsiders' research regimes that narrowly focus on technique rather than on productive and high-value insight.[19] To avert the limitations of certain disciplinary and institutional methods, collaborative research of the kind undertaken by the small NGOs with indigenous and local peoples of the Gran Chaco and the more practiced and refined nodal information networks of Bali's water temples can offer a new way forward.

We have immediate recent experience of the limitations and high risk involved in high-level and large-scale management of global financial systems, and we also have abundant evidence of how equally, if not more, complex systems have been successfully described and sustained through changes that defy abilities to forecast. It would benefit everyone if our best understanding of indigenous methods of describing and manipulating both social and ecological systems were more widely and deeply shared across disciplinary boundaries and with global thought leaders and policymakers.

Bali's nodal temple network is not an accident. It is a paradigm that is worth repeating in as many places as possible. There is already indication that replicating it in the Gran Chaco has gained traction—this initiative simply needs greater support to build a more extensive network and many redundant connects through the enormous ecosystem that it represents.

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PHOTO CREDITS:

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"Bali Temple Scribes" Steve Lansing
"Rice terraces near Gunung Kawi, Bali" Mike Kopetski
"Parapeti Up River-Down River Network, Gran Capitan Bonifacio Barrientos, Isoso" Alejo Zarzycki

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