Transformation of Resource Management Institutions under Globalization: The Case of Songgye Community Forests in South Korea

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Abstract:
The context in which many self-governing commons systems operate will likely be significantly altered as globalization processes play out over the next few decades. Such dramatic changes will induce some systems to fail and subsequently transform rather than merely adapt. Despite this foreseeable trend, the research on globalization-induced transformations of social-ecological systems (SESs) is still underexplored. This study seeks to help fill this gap by exploring patterns of transformation in SESs and the question of what factors help explain the persistence of cooperation in the use of common-pool resources through transformative change. Analyzing 89 forest commons in South Korea that experienced such transformations, we find the following: 1) two broader types of transformation are observed, cooperative and non-cooperative; 2) two properties of social connectedness within forest organization, the number of user groups (villages) and the ratio of cross-institutional links, are associated with the extent to which user groups maintain cooperation through transformation; 3) the ratio of cross institutional links is positively associated with cooperative transformations while number of user groups is negatively associated with the same outcome; and 4) biophysical conditions of the location of user groups may have affected the type of social connectedness that developed in the region.

Keywords:
Transformation, Social-Ecological Systems, Polycentricity

Transformation of Resource Management Institutions under Globalization: The Case of Songgye Community Forests in South Korea

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INTRODUCTION

Studies of commons dilemmas have often focused on investigating factors that affect whether and how institutions succeed or fail in enabling collective action in social-ecological systems (SESs) (Ostrom 1990, 2005a, National Research Council 2002, Poteete et al. 2010). This work has typically been static in nature - the biophysical, social, economic, and institutional factors that define the context in which the agents interact are assumed fixed. Recently, scholars have begun to view commons dilemmas through a dynamic lens and focus on what factors affect the capacity of SESs to cope with change. One way SESs cope with change is through transformative change, a process that occurs when ecological, economic, or social structures make the existing system untenable and a fundamentally new system is created in response (Walker et al. 2004, Folke et al. 2010).

In this article, we build on this foundation to explore transformation patterns of SESs and the question of what factors help explain the persistence of effective collective action in the management of common-pool resources in SESs under conditions that will likely be realized in the next few decades as a result of globalization. Specifically, scholars suggest that globalization will connect SESs across multiple temporal and spatial scales, dramatically changing the context in which many self-governed common-pool resource (CPR) systems operate (Young et al. 2006, Cifdaloz et al. 2010, Anderies and Janssen 2011). One of the ways that such global inter-connectedness can impact small-scale CPR systems is by increasing the inflow of substitute goods for CPRs or the opportunity cost of labor that will nullify the salience of CPRs for local livelihoods (Poteete and Ostrom 2004, Araral 2009). Such dramatic changes in context will likely induce some systems to fail and subsequently transform rather than merely adapt. Systematic research on post-failure transformation is rare in the commons literature (although see Abel, Cumming, and Anderies 2006), and the connection between different transformation paths and their determinants remains poorly understood (Rudel 2011).

Investigating this research question is important for three reasons. First, an increasing number of CPR systems will likely undergo failures and transformations as globalization intensifies. As mentioned above, as globalization proceeds, SESs will increasingly find themselves embedded in globally inter-

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connected systems and exposed to novel disturbances more than ever before (Young et al. 2006, Adger et al. 2009). Second, transformations can trigger collective action problems. Specifically, as existing self-governed systems become untenable as a result of global changes, social actors will likely be confronted with dilemmas linked to the release and reorganization of their natural capital. Some actors may prefer the immediate benefit of selling out natural capital and taking their share of the proceeds over the uncertain long-term benefit of maintaining cooperation in some alternative ways. A better understanding of this post-failure dilemma is needed. Third, due to cross-scale interdependencies, how transformations are coordinated at one scale can fundamentally affect the robustness or resilience of encapsulating systems in another scale (Kinzig et al. 2006, Folke et al. 2010, Anderies et al. 2012). Transformation of nested systems can have important influences on the dynamics of overarching systems (Gunderson and Holling 2002).

In the literature, there are a number of studies that explore the reorganization of SESs in a different light. For example, several case studies investigate the struggles of local SESs subjected to novel disturbances such as increased market pressure (Wunder et al. 2008, Silva et al. 2010), flows of people or intruders (Pérez et al. 2011), or development (Wollenberg et al. 2006, Levang et al. 2007). These studies focus on particular aspects of disturbances and ensuing responses themselves rather than the details of transformation. In another set of studies, scholars exclusively analyze transformations (Olsson et al. 2004, Biggs et al. 2010, Gelcich et al. 2010). These studies, however, either do not involve CPRs or rely heavily on single or small-N cases related to very specific contexts. A single case study or small-N set of case studies can reveal rich insights about a particular setting, but their findings cannot easily translate into theoretical analysis or understanding about broader patterns and structures regarding determinants of successful transformations (Basurto and Ostrom 2009, Bermeo 2010). Lastly, some studies approach the subject from the perspective of long-term vulnerability and transformation (Anderies 2006, Nelson et al. 2010, Anderies and Hegmon 2011, Spielmann et al. 2011). These studies rely on a single case or small-N set of archeological cases populated with very coarse data, and focus on aspects of robustness tradeoffs and vulnerabilities to unfamiliar disturbances that emerge when SESs optimize for a familiar set of disturbances.

This research complements the existing literature by examining 89 forest commons in the Geumsan region of South Korea (Kang 2002) (Fig. 1). After lasting for hundreds of years, these CPR systems all collapsed and experienced transformations, e.g., conservation of natural capital, conversion to new community infrastructure, selling-out, etc., as South Korea rapidly developed and became globalized in the second half of the 20th century. Because this set of cases is large-N and provides accounts of a range of different transformations under globalization, a careful analysis may offer potential lessons regarding the patterns of transformation and some of the possible determinants of transformation.

This article tackles three research questions. First, what are the patterns of transformations undergone by the 89 CPR systems? Unlike the dichotomous classification of either robust or collapsed SESs (Anderies et al. 2004), transformations can involve multiple trajectories of system reorganization. Second, what are some of the key factors that influence the persistence of effective collective action in the management of

shared resources even through transformations? Here, we focus on system-level factors, e.g., connectedness among social modules, rather than explicit household-level or situational factors that are commonly emphasized in single or small-N case studies, e.g., existence of visionary leaders. Our focus on system-level factors is motivated by recognizing that SESs are complex adaptive systems (Levin and Clark 2009) in which emergent, system-level properties interact with individual-level properties to generate system dynamics. As such, system-level factors are important for understanding transformations as is the case with robustness or resilience (Anderies and Janssen 2011). Third, are there tradeoffs between optimizing to particular past conditions and transformative capacity? Most SESs are human-engineered feedback control systems that exhibit inherent robustness tradeoffs to different internal or external perturbations (Janssen et al. 2007). Here, we investigate whether a CPR system that may have become optimized for robustness to past conditions ends up having reduced transformative capacity toward sustained collective action.

METHODS

The study system

The Geumsan region sits in the central inland of South Korea and encompasses 576 km^2. The landscape of the region is roughly characterized by a large central flat valley and surrounding mountain ranges with forests (Fig. 1). The region contains 10 administrative districts that further divide into dozens of sub-districts. Hundreds of villages are interspersed throughout the area. Songgye (pronounced like "song-geh") is the name for the traditional Korean forest organization that was established for setting up community-owned mountainous forests (a common property), appropriating firewood and organic compost in general, and for providing public goods necessary for governing collective action (Park 2000, Kang 2002, Chun and Tak 2009). Many instances of songgye operated in the Geumsan region for hundreds of years until they functionally became obsolete in the mid 20th century (Kang 2002). Until the advent of globalization, access to firewood (pruned tree branches) and organic composts (made from weedy plants growing inside forests) was an absolute necessity for most commoners in the country: the Korean winters are cold and long, agricultural productivity was essential for subsistence, and no substitutable resources were available (Kang 2002, Chun and Tak 2009).

The main role of a songgye (plural – songgye) as a resource management organization was to provide three important public goods. First, songgye provided institutions in the form of appropriation rules. For example, cutting down trees for firewood was usually prohibited, and members could only collect branches during specified time periods few times a year (Park 2000, Kang 2002, Chun and Tak 2009). For distributing harvests, various mechanisms, such as lotteries or payment of modest fees, were employed to allocate harvests that varied in quality (Park 2000, Kang 2002).

Second, songgye systems enabled communities to tackle challenges of infrastructure provision. Through a songgye, member households could collectively purchase a mountainous forest as common property (Kang 2002), a threshold public good that requires investments up to a certain level in order to provide

fully serviceable goods. Villagers also cooperated through a songgye to build and repair mountain trails, which were essential for appropriators to traverse through deep mountains and harvest the resources consisting of pruned tree branches and weedy plants (Kang 2002).

Thirdly, songgye systems facilitated monitoring of rule compliance and sanctioning of unauthorized activities. Some songgye systems had dedicated guards while others had staff or ordinary members playing dual roles for guarding against intruders or rule-breakers(Kang 2002, Chun 2003). Various incentives existed: guards could be given salaries, be allowed to keep harvests and fines that were seized, or be granted rights to perform dry-field farming inside songgye mountains (Kang 2002).

Fig. 1. Map of Geumsan, South Korea. Light yellow area in the magnified map indicates the terrains of flat and lower slopes and roughly approximates the flat valleys. Green area indicates the mountainous terrains. The letters A to J in the magnified map indicate 10 administrative districts of Geumsan.
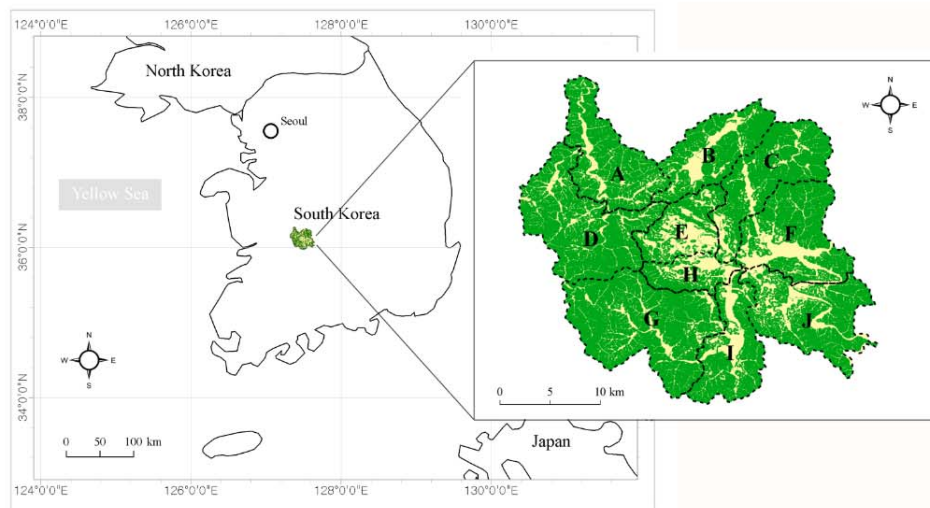
With the onset of industrialization in South Korea from the 1960s and 70s, the use of fossil-fuel products, e.g., coal, coal briquettes, and commercial fertilizers began to spread widely in the region (Kang 2002). This rapidly lowered the economic value of firewood and organic composts and their salience for livelihoods, significantly weakening the function of songgye in Geumsan from the early 1960's (Kang 2002). In fact, no sightings of active songgye activities have been reported from the early 1960's in the region (Kang 2002). Consistent with the findings of a meta-analysis (Poteete and Ostrom 2004), Kang (2002) attributes the main cause of the collapse of songgye to the tempered economic salience of the key

forest resources they were designed to govern. After their collapse, the songgye systems followed a number of different trajectories of transformation and reorganized themselves in their new settings. For instance, some discontinued cooperative resource management by selling their ancestral forests for private gains (proceeds from the sale of the mountainous forest on the market were distributed to private citizens who were members of the songgye) while others maintained cooperation in novel ways by either conserving their forests or selling them to fund projects that provided alternative public goods, e.g., village roads, bridges, community centers, etc.

In tandem, a number of shifting sociopolitical trends also pervaded the region and most likely affected the decisions of local villagers as they weighed different options for reorganizing their CPR systems. For example, starting from the early 1960's, a series of reforestation policies was introduced to revitalize forests that were devastated by the Korean War (1950-1953) and past overharvesting (Chun and Tak 2009). Rural villages were encouraged to organize tree-planting initiatives and to curb timber logging or other types of harvesting activities such as slash-and-burn farming within mountain areas (Kang 2002). In Geumsan, this trend most likely reduced the utility of continuing to manage forests through songgye institutions.

Another trend was the air of post-war recovery and rural development efforts that often translated into calls for repairing or building village infrastructure (Kang 2002). Kang (2002) suggests that motivations to fund such development projects may have influenced villages to sell their songgye mountains.

In another example, there were instances of unclear property rights regarding songgye forests. During the Japanese occupation period (1910-1945), a forest policy was introduced to restructure the traditional forest ownership and tenure system. Under this policy, songgye mountains were denied for registration as commons. As such, the surviving songgye systems in Geumsan had to register their forests as private properties under the names of village leaders (Kang 2002). This made the forests privately owned de jure but de facto commons.

Finally, a real-estate boom pervaded the region throughout the 1980's and 90's (Kang 2002). As a side effect of the rapid economic development, the value of songgye forests as a real-estate commodity increased significantly around this time while the benefits that could be extracted from forestry became further obscured (Kang 2002). This shifting valuation most likely influenced the decisions of local villagers.

Framework

Growing theoretical literature on collective action posits that a large number of contextual factors potentially affect the likelihood of individuals solving collective action problems (Agrawal 2002, Ostrom 2005b, Poteete et al. 2010). Here, to identify relevant contextual factors and to compare user interactions and resulting outcomes across the transformation cases, we employ the multi-tiered

ontological framework of SESs (Ostrom 2007, 2009). The main components of the framework adapted to the songgye cases are shown in Fig. 2. Each main component contains detailed attributes in the lower tier (for details, see Ostrom 2009; Ostrom 2007). To use the framework, analysts do not need to examine all variables but rather those that are thought to be most relevant for a given context (Fleischman et al. 2010).

Using the framework, we identify relevant similarities and differences in contextual factors and type of transformation among the empirical cases. Then, we search for plausible models for the relationship between type of transformation and the differences in contextual factors. This approach closely reflects the methodological challenge raised by Basurto and Ostrom (2009). They call for rich data-driven research, asserting that scholars should look for similarities and differences from rich details across multiple cases and combine theories to detect patterned structures. The claim is that such an approach can generate hypotheses and thus catalyze theory building efforts.

Fig. 2. Adaptation of the first tier of the SES framework (Ostrom 2007, 2009) to the songgye cases.
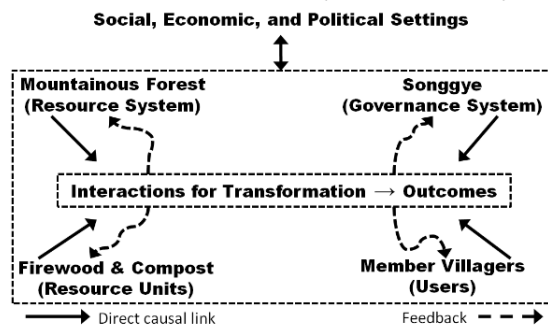
Data source

The primary source of data is the large-N set of cases described in Kang (2002). The study by Kang (2002) was a pioneering local history research project that unveiled the details of the forgotten tradition of songgye. As the main output, the study delivered descriptions of 156 songgye systems that had existed in the Geumsan region. The study took 10 years to complete, involved 80 intensive site visits and analysis of dozens of archival documents, and involved interviewing 391 elderly local villagers.

Here, we select 89 cases from the total of 156 by sampling the cases that satisfy both of the following conditions: 1) time coincidence of transformation events with the onset of economic development in South Korea (1960~) and 2) presence of key variables, e.g., outcome of transformation, size of resource system, etc. The first condition ensures that we are addressing the research problem of investigating the transformation of SESs under the influence of globalization. Because the region under study started to

face the effects of globalization-induced industrialization from the 1960s and 70s on (Kang 2002), our scope of analysis involves the initial transformation process undergone by songgye systems in the period between 1960 and 1999. A word of caution about sampling bias is in order here. Because of the sampling criteria above, we are actually sampling on the cases of more persistent songgye systems than all representative ones. Hence, any causal claims made throughout the paper should be interpreted in relative terms in the sense of the bias created here.

PATTERNS OF TRANSFORMATION

By the early 1960s, all songgye systems in Geumsan had become dysfunctional and collapsed from the emergence of substitute goods for forest products, and subsequently began to be influenced by shifting sociopolitical trends (Kang 2002). In the ensuing post-failure reorganization phases, participating villages interacted in a one-shot game setting to decide the fate of their now-obsolete mountainous forests. Depending on the number of participating villages in a songgye, either a single village or multiple villages interacted in the decision-making process (Kang 2002). The arena of interaction was most likely village meetings. All members of a village assembly could voice their opinions and, if voting was necessary for the decision-making process, could cast a vote (Kang 2002). In general, two broad types of actions were possible: 1) favoring short-term maximization of self-interest, e.g., support the sell out of the communal forest and divide the proceeds among households, and 2) maintaining cooperative management in alternative ways, e.g., support the conservation of the forest or its liquidation and conversion to other public goods. A village consensus (unanimous or almost unanimous agreement) or voting (some sort of majority rule) was generally used for decision-making at the village level, and the decision reached was binding for all members (Kang 2002). When multiple villages were involved, decisions were usually made through two stages – each village would first decide on its preference and then all involved villages would have to agree unanimously if their shared assets were to be liquidated for other purposes (Kang 2002).

Several patterns of outcomes of these transformations are observed. In pattern A, villages chose to maintain cooperative governance regimes and conserved their forests intact (Kang 2002). In such cases, resource systems that had provided direct use values essentially transformed into public goods with existence values. In pattern B, villages sold some or all of their forest resource systems and used the revenue raised to establish alternative community infrastructure. Examples include building village roads, bridges, and electric power lines; purchasing arable lands for communal farming; constructing schools and community centers; and establishing communal funds (Kang 2002). In essence, these villages maintained their cooperative governance regimes in novel ways by converting their natural capital into new types of infrastructure that better met the modern-day needs of their communities. Pattern C is characterized by the release of some or all of the relevant natural capital with nothing contributing back to collective welfare. Motivated by short-term, self-interest maximization, villages in these instances sold their natural capital and simply divided among households whatever financial return they could get (Kang 2002). In pattern D, instances of property right disputes motivated by unclear land

titles are observed. Despite the possibility of settling the conflict and preserving their communal forests, villagers in these instances failed to generate enough collective action (collecting fees for upfront legal charges) to initiate formal legal actions. In such cases, resource systems fell into the hands of few opportunistic stakeholders (Kang 2002).

Here, we further compact the four observed patterns, A through D, into two broader patterns based on the degree of persistence of cooperation: 1) cooperative transformation and 2) non-cooperative transformation. In the cooperative transformations, the common-pool resources provided by the forest tend to be transformed into public goods and cooperative governance is maintained in alternative forms. Pattern A and B belong to this category. In the non-cooperative transformations, all of the forest resources are transformed into private gains, and cooperative governance is discontinued. Pattern C and D belong to this category. The category of transformation (1 or 2) constitutes our dependent categorical variable in the statistical analysis.

CONTEXT OF TRANSFORMATION

In this section, we discuss contextual factors that are judged to be important for addressing our research questions. These factors are potentially associated with the patterns of transformation identified above. and will be used to construct the explanatory variables in the statistical analyis.

Social connectedness

A complex mesh of village-level social connectedness developed in Geumsan as the villages adopted varying structures of multi-level governance for the implementation of their songgye governance regimes. Built on the structure of horizontal and vertical social linkages, multi-level governance is defined as having multiple centers or authorities of management and arrangements where collective action is organized in multiple layers of nested enterprises (Ostrom 1990, Lebel et al. 2006, Cox and Arnold 2010).

In Geumsan, three historical strategies played key roles for the manifestation of multi-level governance and the resulting pattern of social connectedness: 1) multiple-village cooperation, 2) redundancy in cooperation, and 3) vertical nesting within village assemblies. Multiple-village cooperation occurred whenever two or more villages formed an allied songgye by co-purchasing a resource system and performing joint appropriation and provision activities under the supervision of a loosely formed inter-village council (Kang 2002) (Fig. 3 (b), (c), and (d)). This practice reflects the design principle of nested enterprises in governing the commons (Ostrom 1990). We speculate that the resulting economy of scale and modularity of social systems better facilitated the provision of threshold public goods such as purchasing a large-scale mountainous forest and building and repairing mountain trails. For example, for purchasing a large-scale resource system, multiple villages acted together to increase their total group size and delegated each village to pool financial contributions from its member households (Kang 2002).

In this way, these allied villages were able to increase the level of provision of the public good while decreasing the size of individual contributions and coordination costs. Similarly, for building and repairing mountain trails, each village was assigned with a dedicated section of a network of trails and was responsible for its maintenance (Kang 2002). This, too, increased the level of the public good provided while economizing individual efforts and coordination costs.

Redundancy in cooperation arose whenever villages participated in multiple instances of songgye simultaneously, which resulted in the creation of cross-institutional links across different songgye systems (Fig. 3 (c) and (d)). The resulting redundant links of a village enabled that village to cope with varying biophysical conditions and uncertainties. For example, some villages with existing songgye forests that were either unproductive or too distant from their village locations chose to join another songgye in order to access more productive or nearer forests (Kang 2002). Redundancy is well-known for its potential contributions to robustness or resilience. The idea is that functionally redundant systems have more variability in response (response diversity) to different social-ecological conditions and thus better maintain system functions under uncertainty (Elmqvist et al. 2003, Folke et al. 2005).

Vertical nesting occurred whenever songgye-related affairs in a single village were nested under that villages' assembly (Fig. 4). The village assembly, an overarching village organization that oversaw all types of coordinated tasks in a single village, existed for every village in the region (Kang 2002). Entire cases of songgye in Geumsan practiced vertical nesting (Kang 2002). We speculate that, through vertical nesting, a songgye could economize transaction costs by tapping into established leadership and legitimacy that already existed with village assembly. An additional layer of nesting occurred for multiple-village songgye systems because they were coordinated by inter-village councils (Fig. 4 (b)).

Lastly, some interesting configurations of overlap between ecological boundaries of mountainous forests and social boundaries of songgye systems are observed [3]. For example, some songgye systems had multiple physically separated mountainous forests under single social boundaries (Fig. 4 (e)). In other instances, multiple songgye systems had their forests co-located on the same mountain (e.g., one songgye utilizing one area on the lower reaches of a large mountain and the second songgye operating on another area on the lower reaches of the mountain) (Fig. 4 (f)).

Village location

Depending on where villages are located, we speculate that the villages faced two biosocial heterogeneities in the past: 1) variation in availability of forest resources in their immediate surroundings and 2) variation in degree of village-to-village social connectivity.

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[3] Although we are aware that these types of configurations existed, there is incomplete data in our hand to systematically analyze their effects on the operation and transformation of songgye systems. Therefore, the analysis of such configurations is left to subsequent research.

Most of the villages in the central districts (district E and H in Fig. 1) are located on flat areas, and therefore, lacked access to forests in their immediate surroundings. In the perimeter districts of B, C, F, I, and J, multiple types of landscapes are observed. Here, clusters of flat areas and mountainous terrains coexist in closer proximity. Kang (2002) suggests that the flat areas in the central and perimeter districts were more populous areas where villages tended to link seamlessly to one another without major spatial barriers. Most of the villages here probably had more neighboring villages and better inter-village social connectivity but less ease in finding harvestable forests nearby (Kang 2002). In contrast, most of the villages located in the mountainous areas (district A, D, and G and parts of district B, C, F, I, and J) tend to be isolated spatially by the natural barriers of mountain ranges. Inter-village social connectivity was probably lower there in the past, but these villages had better access to mountainous forests (Kang 2002).

Resource systems and units

Mountainous forests varied among songgye systems in terms of size and/or terrain characteristics. Some forests were large in area, encompassing as much as few hundred hectares. Some forests also differed in resource potential by having mostly rocky or gentle sloping terrains. Regarding resource units, mainly harvested items were firewood and organic materials for composts (Kang 2002). Some cases of songgye, however, were different in that they additionally exercised considerable dry-field farming inside their mountain regions as well as allowing tenants to take over the farming in exchange for annual tenant fees (Kang 2002). In such cases, the collected fees became an important source of income for covering miscellaneous operating expenses of songgye (Kang 2002).

Fig. 3. Types of village-to-songgye social connectedness. The link between a village and a forest represents a share in the property right of the forest and a participation in joint appropriation and provision activities. Triangles represent the biophysical boundary of the forest which is determined naturally by the physical boundary of a mountain along a contiguous ranges of mountains. The dashed rectangles indicate the institutional boundary of the songgye.

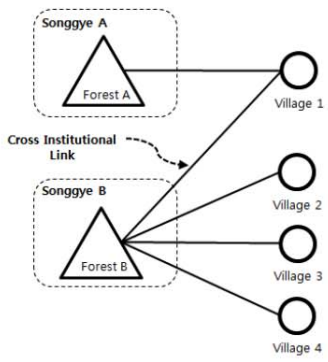(a) Songgye A : single-village without cross institutional link.

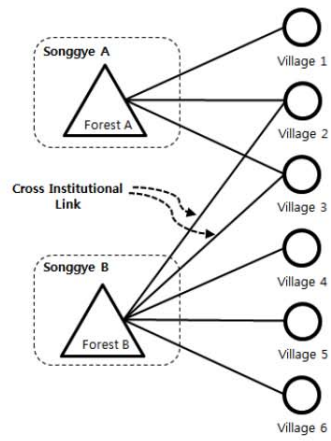(b) Songgye A : multiple-villages without cross institutional link.
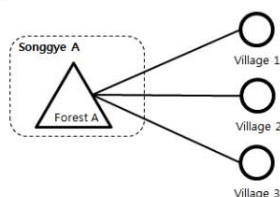
(c) Songgye A : single-village with cross a institutional link.

(d) Songgye A : multiple-villages with cross institutional links.

(e) Songgye A : single-village with multiple forests.

(f) Songgye A : single-village with a partitioned forest.
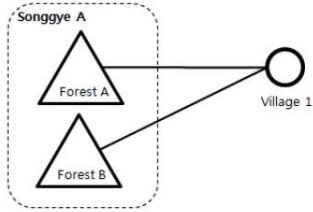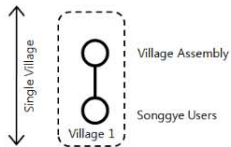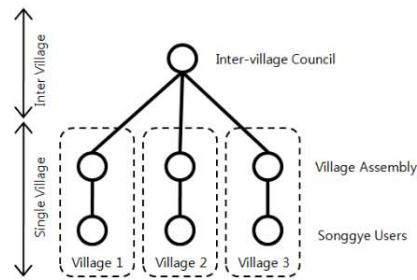

Fig. 4. Types of vertical linkages in songgye social structure.

(a) A single-village songgye with nested social structure.

(b) A multiple-village songgye with nested social structure.

Summary: similarities and differences

Based on the analysis so far, we outline in Table 1 some key similarities and differences (explanatory variables) across the cases for the period between 1960s and 90s. Note that most of the similarities relate to the shifting social, economic, and political trends, i.e., exogenous disturbances, that are general and pervasive in nature. Because the songgye systems under study all derive from a single rural region that is mono-ethnic and -cultural in user characteristics, it is reasonable to assume that most of the songgye systems practically experienced the same shifting social, economic, and political trends. Therefore, from a system-level perspective, notable differences across the cases mostly concerned the specifics of social connectedness and variations in villages' location and topographic position and resource systems and units. Although the listed variables in Table 2 are not exhaustive, they largely cover the relevant information for this research. Table 2 describes the variable definitions and measurements.

Table 1. Similarities and differences across the large-N cases.

Similarities	Differences (Variables)
Reduced economic salience of CPRs due to emergence of substitute goods	Outcome of transformation
	Number of villages, i.e., number of horizontally linked
Rapid economic development	villages under a songgye
Real-estate boom	Ratio of cross-institutional links
Reforestation policy by the government	Spatial extent of villages
Post-war recovery efforts	Topographic location of villages
Unclear property rights	Size of resource systems
History of use	Terrain of resource system
Similar socioeconomic attributes of users	Existence of tenant fees (for dry-field farming)
Democratic voting rules for the decision-making	

Table 2. Variable descriptions.

Variables	Definitions
Dependent variable:	
Outcome of transformation	The outcome of transformation is categorized into two broad types: (1) cooperative transformation and (2) non-cooperative transformation ($=1$ if cooperative; $=0$ if non-cooperative).
Independent variables:	
Number of villages	A number of villages in a songgye that are horizontally linked through shared property rights of a resource system and joint appropriation and provision activities. For the songgye 'A' in Fig. 3 (a) and (c), this measure is 1. In Fig. 3 (b) and (d), this measure is 3.
Ratio of cross-institutional links	The ratio of cross-institutional links measures the percentage of participating villages in a songgye that participate in multiple instances of songgye

	simultaneously . For the songgye 'A' in Fig. 3 (a) and (b), this measure is 0. In Fig. 3 (c), this is 100%. In Fig. 3 (d), this is 2/3 or 67%.
Spatial extent of villages	The spatial extent is measured by the scale of administrative districts spanned by participating villages (=0 if one village is involved; =1 if multiple villages are involved but all are situated within one sub-district; and =2 if multiple villages are involved and are situated over multiple sub-districts).
Topographic location of villages	The percentages of flat areas in the surrounding areas of participating villages are averaged to derive this measure .
Size of resource system	The size of resource system measures the physical area covered by a songgye's mountainous forest(s) (=0 if 1-10 hectares; =1 if 11-100 hectares; and =2 if greater than 100 hectares) .
Terrain of resource system	The terrain type is estimated from the existence of considerable dry-field farming inside songgye mountains (=1 if considerable dry-field farming exists, i.e., presence of large mildly-sloping terrain; =0 otherwise).
Existence of tenant fees	The functional diversity carried by resource system is measured by the existence of annual tenant fees levied for the rights to exercise dry-field farming inside songgye mountains. It gauges whether or not the villages were able to extract extra benefits from their mountains (=1 if annual tenant fees were collected; =0 otherwise).

DATA ANALYSIS

To relate the likelihood of cooperative transformation to the contextual factors, we used multivariate logistic-regression models. We used a model selection approach to hypothesis testing (Johnson and Omland 2004). We applied the Akaike Information Criterion (AIC) method to compare the fits of all possible combinations of explanatory variables (Burnham and Anderson 2002). AIC is calculated for a suite of models and the best-fitting model has the smallest AIC. The absolute size of the AIC is unimportant; instead the difference in AIC values between models indicates the relative support for the models. In order to compare models, we calculate Akaike weights (Burnham and Anderson 2002). The Akaike weight is the probability that a model would be selected as the best fitting model if the data were collected again under identical circumstances. For the set of models, Akaike weights sum to 1. A model whose Akaike weight is close to 1 is unambiguously supported by the data (Burnham and Anderson 2002). We consider as plausible models those with Akaike weights that are within 10% of the highest weight. We also report the relative variable importance as the sum of Akaike weights over all models including the explanatory variable. The relative variable importance is the probability that, of the

variables considered, a certain variable is in the best approximating model. We calculated the model averaged estimates weighted by its Akaike weight (Burnham and Anderson 2002).

Lastly, we perform correlation analyses for the relationship between topographic location of villages and songgye-related social connectedness of villages, an emergent system-level property related to robustness of songgye social systems. If this system-level property is associated with topographic location and also with different trajectories of transformation, we could infer that optimizing for robustness (i.e., forming social connectedness) to past conditions (i.e., variations in resource flow stemming from topographic location) possibly affected the transformative capacity of songgye users.

RESULTS

Descriptive statistics

The majority (73%) of the transformations were cooperative, i.e., Pattern A and B, with the rest being non-cooperative (Table 3). Some of the notable trends in descriptive statistics are the contrasts in the averages of a number of villages involved and ratios of cross-institutional links (Tables 4 and 5). The average of the former factor among the cooperative transformations is lower (2.2) than its counterpart (6.3). The average of the latter factor among the cooperative cases is higher (0.6) than that of the non-cooperative cases (0.3).

Table 3. Summary statistics of patterns of transformation.

Patterns of transformation, (N=89)	Frequency (%)
Cooperative transformation	
-Pattern A	36 (40%)
-Pattern B	29 (33%)
Non-cooperative transformation	
-Pattern C	19 (21%)
-Pattern D	5 (6%)

Table 4. Categorical variable statistics by cooperative and non-cooperative transformations. For legend, see Table 2.

Variables	Non-cooperative transformation (N=24)			Cooperative transformation (N=65)		
	Frequency (%)			Frequency (%)		
	(=0)	(=1)	(=2)	(=0)	(=1)	(=2)
Size of resource system	5 (21%)	13 (54%)	6 (25%)	19 (29%)	36 (55%)	10 (15%)
Terrain of resource system	13 (54%)	11 (46%)		44 (68%)	21 (32%)	
Existence of tenant fees	6 (25%)	18 (75%)		25 (38%)	40 (62%)	
Spatial extent of villages	11 (46%)	5 (21%)	8 (33%)	42 (65%)	10 (15%)	13 (13%)

Model Selection

The model selection results suggested that 20 models could be considered as plausible models (i.e., those models with akaike weights that are within 10% of the highest weight) (see Table 6 in the Appendix). Given the data and set of candidate models, the best explanatory model is the one that included the independent variables number of villages and ratio of cross-institutional links. The former variable was included in all of the plausible models with a negative response. The latter variable had a probability of 0.87 of being in the best approximating model with a positive response. Thus, cooperative outcomes were associated with lower number of villages and higher proportion of cross-linked villages. The variable existence of tenant fees had a probability close to 0.5 of being in the best model and with the previous two variables formed the second plausible model. The association of outcomes with existence of tenant fees was negative. The third model added the variable terrain of resource system to the best model. This variable had a probability of 0.31 with a negative coefficient, meaning that the existence of large-scale dry-field farming (i.e., presence of mildly-sloped terrains in mountainous forests) leads to less cooperative transformations. The fourth model added the variable topographic location of villages to the best model. This variable had a probability of 0.32 of being in the best fitting model and its response was negative, meaning that songgye systems with villages located on more flat valley areas tend to transform less cooperatively. The variable size of resource system was added in the fifth plausible model. This variable had a probability of 0.31 with a positive coefficient, meaning that cooperative outcomes are associated with larger resource system sizes. Finally, the variable 'spatial extent of villages' first appears in the 17th plausible model. This variable had a low probability (0.14) of being in the best fitting model with a positive coefficient.

Association between social connectedness and biophysical context

Correlation analyses were performed to test whether the biophysical context (topographic location) of a village is associated with varying forms of social connectedness that developed as a part of villages pursuing multi-level governance regimes. If there is a significant association, we may be able to infer that the different structures of social connectedness developed in the region in part by the villages trying to optimize to their surrounding biophysical context.

We first tested the association between the topographic location (i.e,. degree of flat terrains[4]) in which a village is situated and the number of villages for each songgye that the village belonged to[5]. The association is significant (p-value < 0.001) with a modest correlation (Pearson's r=0.365). This suggests

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[4] Topographic position index (TPI) (Weiss 2001) is derived for each sub-district that contains member villages. For each sub-district, areas of flat and lower slopes are divided by the total sub-district area to derive the percentage of flat terrains.
[5] Here, our unit of analysis is associations between a village and its participations in one or more songgyes. Because we are dealing with past robustness, we apply all 156 cases of songgye as the sample. Since some villages joined more than one songgye, the total count of associations is 501 (although the total number of villages is 338).

that a village situated on a flat valley is more likely to be a member of a multiple-village songgye than a village located on mountainous areas. This makes an intuitive sense: with more neighbors and less resource availability in immediate surroundings, a village located on a valley probably had more incentives to cooperate with others to economize costs of operating a songgye. Second, we tested the association between the topographic location and whether a village carried at least one cross-institutional link. There is no significant association (p-value > 0.05) and the two variables are weakly correlated.

DISCUSSION

This research began with the assertion that given the process of globalization now underway, the study of the commons needs to not only address whether cooperation arises or fails in a given set of biophysical, social, and economic circumstances, but also begin to understand the dynamics of cooperation as those circumstances change. Here we focus on some dimensions of post-failure processes and the question of what factors help explain the nature of post-failure transformation of self-governing CPR systems. In the current body of literature, we found no studies that directly attempted to answer this question in a structured way. Most of the studies either focused on relationships among aspects of disturbances, responses, and vulnerability tradeoffs or depended on either a single or a small-N set of cases that could not offer understanding of underlying structure for observed patterns of transformation in a statistically significant way.

By analyzing 89 songgye forest commons that underwent transformations under globalization, we sought to complement the existing body of literature and tackle three specific questions: 1) what are the patterns of transformations experienced by songgye systems; 2) what are some of the factors that influence whether cooperation is maintained in novel ways through transformation; and 3) can there be tradeoffs (i.e. a negative correlation) between optimizing for particular past conditions and transformative capacity exhibited by songgye users.

Regarding the first question, we find that the songgye systems in Geumsan underwent either cooperative or non-cooperative transformations. The majority of the observed transformations are cooperative (65 out of 89). The presence of the two broader trajectories of transformation simply reflects the nature of a dilemma faced by the users: whether to continue to pursue some social welfare as they had or conveniently opt for private gains. The fact that the majority of the observed transformations are cooperative garners some explanation. As already pointed, the sampling bias introduced by selecting only those songgye systems that remained intact until the early 1960s indicates something about the nature of our sample. Our sample probably consisted of villages that exhibited inherently higher levels of social capital. This may explain why the majority of the observed transformations pursued some form of collective welfare in spite of the apparent temptation to defect and pursue private gains.

Second, the best-fitting model shows that the number of villages is negatively associated with cooperative transformations, while the ratio of cross-institutional links is positively associated with the same outcome. The direction of association exhibited by the number of villages is consistent with the transaction cost hypothesis of group size – the more participants there are in a collective action problem, the more difficult it would be to organize collective action due to higher coordination or transaction costs (Ostrom 2005a, Araral 2009, Poteete et al. 2010). Because participant villages in a songgye act cohesively as single actors at the system-level, the number of member villages is a scale-invariant representation of group size. As such, songgye systems with higher counts of member villages probably faced greater transaction costs and thus were less likely to maintain collective action through transformations. This speculation is consistent with the observed patterns in our sample data. One might ask then why such songgye systems with large group sizes even existed in the first place. In the past, their emergence was probably possible or even welcomed because the salience of firewood and organic compost for villager livelihoods was high and many of the relevant units of public infrastructure, e.g., mountain trails, were threshold public goods that required economy of scale in contributions of human effort.

What catches our attention is the positive association between the ratio of cross-institutional links and the prospect of villages engaging in more cooperative transformations. Cross-institutional links arise when villages attempt to build redundancy by participating in multiple resource institutions simultaneously. We speculate that those villages in Geumsan with cross-institutional links may have functioned as bridging actors or connectors within their respective action situations of transformation (Westley 1995, Gladwell 2000). Through their cross linkages, these social systems most likely facilitated more rapid exchanges of diverse information across different songgye systems. In fact, this configuration resembles a small-world network which allows more rapid and far-reaching traversal of network nodes (Watts and Strogatz 1998). We speculate that through such cross links, social systems could accumulate more diverse and up-to-date experiences and knowledge useful for solving various coordination problems in the past. Similarly, in the modern-day micro-situations of transformation, the presence of such cross links probably mitigated the pestering problem of information uncertainties regarding available trajectories of transformation and the costs and benefits associated with those trajectories. For example, the presence of bridging or connector villages should have better facilitated circulation of information regarding the serviceability of a new community infrastructure that villagers weren't aware of, what the social value of a conservation or alternative public infrastructure could be, or what the expected market value of a forest might have been if sold.

Next, we find some evidence that there is a potential tradeoff between robustness and transformative capacity of songgye social systems. Our analysis shows that the topographic location of a village and whether that village participated in a multiple-village songgye are significantly associated, i.e., a village situated in an open valley tends to form multiple-village songgye more often than a village in a mountainous area. Given that this social connectedness may have evolved from participating in multi-level governance regimes which are known to enhance adaptive capacity and thus robustness of social

systems (Ostrom 1996, Folke et al. 2005, Marshall 2008), we could infer the following: social connectedness developed in Geumsan as part of the villages' efforts to enhance robustness of resource flows from the forest to variation associated with the biophysical context in which they operated. The emergence of such context-dependent social connectedness probably gave those songgye social systems higher adaptive capacities and thus more robustness to changes and surprises. For example, from the horizontal links of multi-level governance, such songgye systems probably had higher levels of information exchange, local adaptability, and economy of scale for providing collective goods. Further, through cross-institutional links, such songgye systems probably attained higher response diversity and cross-cutting information exchanges. However, when pressures associated with globalization finally necessitated transformations, the advantages of horizontal links no longer applied and the transaction costs associated with horizontal links may have dominated the transformation action situation. This scenario suggests that there might have been a tradeoff between past robustness and transformative capacity of social systems regarding their ability to maintain cooperation through transformations.

Lastly, we discuss the effects of the remaining independent variables. Although these variables were not included in the best-fitting model and thus not significant predictors in our view, we can make the following assessments. The negative associations of the cooperative outcomes with existence of tenant fees, terrain of resource system, and topographic location of villages may imply that when these variables have larger values, the resource systems probably have more favorable terrains and locations and thus more potential for alternative uses. This could mean higher opportunity costs for transforming cooperatively. The positive associations of the cooperative outcomes with size of resource system and spatial extent of villages appear perplexing because the two variables could mean higher opportunity and transaction costs for transforming cooperatively. The hypothesis we have based on a few anecdotal records (Kang 2002) is that some songgye systems with large-scale resource systems spread over multiple sub-districts promised their member villages informal property rights to dedicated areas of their mountainous forests. This informal sub-division of resource system and property rights could have alleviated the opportunity and transaction costs associated with transforming cooperatively.

CONCLUSION

We have used a large-N study to explore the relationship between institutional arrangements, biophysical context, and transformative capacity. If we envisage the liquidation of an asset (forest) and distribution of the cash proceeds from the sale to individual villagers as a failure to sustain cooperation through transformative change, the data suggests that cross-institutional links enhance transformative capacity while system size reduces it. If we further link these social and demographic variables to biophysical context, we can begin to uncover patterns between the adaptation of SESs and their transformative capacity. Specifically, consistent with the adaptive cycle, the transformative capacity is path dependent. The statistics suggest that systems portrayed in Fig. 3 (a) and (c) with relatively small numbers of villages in each songgye would have a higher chance of transforming in a cooperative way. In fact, statistics suggest that a system in Fig. 3 (c) has the highest potential to transform cooperatively –

horizontal links are few and the ratio of cross-institutional links is high. A system in Fig. 3 (b) would be least likely to cooperatively transform because of the transaction cost effect.

Overall, the data points to a balance of different types of social relationships in transformative capacity. We must emphasize that like adaptive capacity, transformative capacity is a relative, scale-dependent concept. Here, we have associated cooperative transformation with higher transformative capacity. However, liquidating forest assets may demonstrate transformative capacity at the individual level. That is, individuals are willing to transform their interactions from traditional, personal, village-scale, in kind exchanges to impersonal, global scale, cash exchanges. Thus, those songgyes that liquidated their forests may simply indicate higher transformability at the individual scale. Understanding how and at what scales transformability operates is important for positioning SESs to cope with global change and will require much more research like that reported here. However, using this set of SESs, we have taken some initial steps in understanding relationships between biophysical context, institutional arrangements, and transformative capacity.

ACKNOWLEDGEMENTS

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APPENDIX

Table 6. Plausible models identified by the AIC method. For each model, the table indicates the coefficient of the variables included, the number of parameters (df), log-likelihood (logLik), delta weight (ΔAIC, difference between the AIC for a given model and the best fitting model), and Akaike weights (w, the model selection probability). Averaged coefficients and the relative variable importance are presented.

	df	(Intercept)	Spatial extent of villages	Existence of tenant fees	Topographic location of villages	Number of member villages	Ratio of cross-institutional links	Terrain of resource systems	Size of resource system	logLik	AICc	w
1	3	1.1059	-	-	-	-1.0601	0.6322	-	-	-44.09	94.19	0.12
2	4	1.1254	-	-0.3664	-	-1.1117	0.6114	-	-	-43.24	94.47	0.10
3	4	1.1091	-	-	-	-1.0242	0.6667	-0.2176	-	-43.78	95.55	0.06
4	4	1.1163	-	-	-0.2259	-0.9973	0.7214	-	-	-43.85	95.70	0.06
5	6	0.9612	-	-0.4227	-	-1.5737	0.6889	-	1.0000	-41.88	95.75	0.05
6	5	1.1409	-	-0.3863	-0.2598	-1.0257	0.7069	-	-	-42.91	95.82	0.05
7	5	0.8885	-	-	-	-1.4457	0.7125	-	1.0000	-42.93	95.85	0.05
8	5	1.1254	-	-0.3348	-	-1.0959	0.6264	-0.0710	-	-43.21	96.42	0.04
9	6	0.8829	-	-	-	-1.4584	0.7606	-0.2790	1.0000	-42.43	96.86	0.03
10	5	1.1238	-	-	-0.2585	-0.9443	0.7760	-0.2464	-	-43.46	96.91	0.03
11	7	0.9199	-	-0.4429	-0.2941	-1.5067	0.8027	-	1.0000	-41.48	96.96	0.03
12	6	0.8402	-	-	-0.2638	-1.3957	0.8240	-	1.0000	-42.61	97.22	0.03
13	3	1.0528	-	-0.4015	-	-0.9802	-	-	-	-45.70	97.40	0.02
14	2	1.0207	-	-	-	-0.9109	-	-	-	-46.78	97.56	0.02
15	7	0.9530	-	-0.3676	-	-1.5649	0.7160	-0.1257	1.0000	-41.79	97.59	0.02
16	6	1.1420	-	-0.3444	-0.2674	-1.0029	0.7315	-0.0942	-	-42.87	97.73	0.02
17	5	0.9564	1.0000	-	-	-1.2842	0.5691	-	-	-43.92	97.83	0.02
18	7	0.8127	-	-	-0.3069	-1.4014	0.9021	-0.3128	1.0000	-42.00	98.00	0.02
19	6	0.9913	1.0000	-0.3573	-	-1.3017	0.5583	-	-	-43.11	98.22	0.02
20	8	0.8989	-	-0.3745	-0.3068	-1.4952	0.8450	-0.1518	1.0000	-41.36	98.73	0.01
Averaged coefficients		1.0230	0.0046	-0.1788	-0.0802	-1.2054	0.6007	-0.0536	-0.0110			
Relative variable importance		1.00	0.14	0.46	0.32	1.00	0.87	0.31	0.31			