

# Corruption and Anti-Corruption in Environmental and Resource Management

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## Keywords

corruption, extractive industries, irrigation, agriculture, forestry, fisheries, conservation

## Abstract

Corruption significantly affects the large majority of countries, and it has negative social and economic impacts. Its impacts on environmental and resource management (ERM) sectors are less well understood. We review corruption in the extractive industries, irrigation, agriculture, forestry, fisheries, and conservation activities with a focus on the management of protected areas and the wildlife trade. There is significant evidence that corruption in ERM sectors is systemic. Corruption in these sectors has significant negative environmental and economic impacts, which can be expected to result in negative social impacts. Many of the anti-corruption policies proposed for the ERM sectors draw on the principal-agent theory. The political science literature on corruption found that theory to have limited application when corruption is systemic and the principal is corrupt. The analysis of corruption and anti-corruption in countries with systemic corruption should draw to a greater extent on collective action theory to identify more effective policies. We highlight some anti-corruption policies relevant to ERM sectors.

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## 1. INTRODUCTION

In his address to the first United Nations (UN) Security Council's meeting on corruption and conflict in September 2018, the Secretary-General stated that every year “the global cost of corruption is at least \$2.6 trillion . . . [and] according to the World Bank, businesses and individuals pay more than \$1 trillion in bribes every year” (1). The true global economic costs of corruption are uncertain, given that the most recent estimate (for 2015) at approximately \$1.5 to \$2 trillion (2) was simply extrapolated on the basis of the earlier estimate of \$1 trillion annually ( $\pm 40\%$ ) (3). Despite this uncertainty, most studies that have used perception-based measures of corruption agree that it negatively affects economic growth (2). By reducing economic growth, as well as affecting the progressivity of the tax system, social spending, the formation of human capital, access to education, and asset ownership, corruption increases income inequality and poverty (4). As a result of their powerlessness, the poor are generally more prone to having to pay bribes to government officials (5) and, in poor countries, more than 80% of the population has experienced corrupt practices in the health sector, resulting in negative impacts on their health (6). Because of these significant global impacts, UN Sustainable Development Goal (SDG) 16 on Peace, Justice and Strong Institutions includes Target 16.5 to “Significantly reduce corruption and bribery in all their forms.” Several other SDGs, including those related to the environment, can be expected to suffer from corruption, given its cross-sectoral nature.

A review of the implications of corruption for policy in natural resource management highlighted that corruption was found across the fuels, minerals, agriculture, and forestry sectors (7). The authors of this review contended that policies to address corruption were needed because corruption has significant negative impacts on economic growth (7). One must also consider the impacts of corruption on the environment to decide whether and what policies might be needed, as highlighted by a debate on corruption and biodiversity that noted uncertainty about whether corruption had positive or negative environmental impacts (7–9).

This review considers how corruption manifests itself across several environmental and resource management (ERM) sectors as well as the known impacts it has on those sectors, and it examines current knowledge about anti-corruption policies in ERM sectors.

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**Corruption:** abuse of authority or power (in public or private sector) for personal gain; a definition based on principal-agent theory

**Bribery:** giving or receiving something of value to influence the actions of someone in a position of authority or power

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We analyze, respectively, the sectors extractive industries, irrigation, agriculture, forestry, fisheries, and conservation with a focus on protected areas (PAs) and the wildlife trade. We consider only briefly the livestock sector because of the very limited number of studies that have addressed corruption in this sector. The sectors are considered individually for several reasons. First, assessing the aggregate global impacts of corruption on the environment has so far proved unviable. A cross-country econometric analysis found a negative relationship between the Environmental Sustainability Index and corruption (10). However, those results are sensitive to the index used to measure sustainability (11). Second, whether corruption impacts a sector can be assessed only by considering it in its own right. Third, considering the details of corruption in the specific sectors while simultaneously addressing several sectors can highlight the relevance of corruption in one sector for other ones. Fourth, the recent literature on corruption and anti-corruption has stressed the need to understand the nature of the corrupt practices in the specific context being analyzed to develop tailored anti-corruption policies.

The analysis of corruption and anti-corruption in ERM sectors benefits from being situated within the broader debate on the theory of corruption and anti-corruption, as well as the analysis of the evidence on the effects of anti-corruption policies. The review proceeds by considering those issues before addressing the literature focused on corruption in ERM.

## 2. DEFINITIONS AND THEORIES OF CORRUPTION

The UN Convention against Corruption came into force in 2005, and 186 countries had ratified it by June 2018 (<https://www.unodc.org/unodc/en/corruption/ratification-status.html>). The Convention is legally binding, making corruption a globally recognized crime. The goals of the Convention include addressing corruption in the public and private sectors in individual countries and across borders. However, corruption is not defined in the UN Convention, given that it recognizes the sovereignty of the State Parties that define it in their legislation. The UN Convention (as with the Organisation for Economic Co-operation and Development's Convention on Combating Bribery of Foreign Public Officials in International Business Transactions and the Council of Europe's Criminal Law Convention on Corruption) mandates international standards on the criminalization of corruption by prescribing specific offences that constitute corruption (12). The offences mandated by the UN Convention include the active and passive bribery of national public officials; active bribery of a foreign or international public official; money laundering; and embezzlement, misappropriation, or other diversions of property by a public official (12). Optional offences listed in the convention include active and passive bribery in the private sector and trading in influence (12).

In academic writings, there is not a single, accepted definition of corruption, partly because there are several manifestations and interpretations of corruption, as exemplified by the offences mandated by the UN Convention. Some scholars even regard seeking to present one definition as not useful or even counterproductive (13–15). The earlier definition of corruption as the abuse of public office for personal gain has evolved into variants that refer to abuse of authority or power, which implies holding of positions in the public or private sector and which can involve holding formal office as well other positions of trust (14). This view of corruption essentially involves an exchange of favors between two actors who deviate from normal, noncorrupt behavior (13, 14). This actor-focused perspective is the basis for the analysis of corruption through the lens of the principal-agent theory that has dominated until recently the analysis of corruption, particularly by economists but also political scientists. In this theory, the principal is assumed to act in the public interest, whereas the agent is self-interested. Moreover, the agent has more information than the principal about the tasks that the former is entrusted with and, because of self-interest, the agent

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**Principal-agent theory:** principal, acting in the public interest, delegates tasks to a self-interested agent whose personal interest conflicts with the principal's interest

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**Systemic corruption:** individuals behave corruptly as a result of institutions/ organization that are weak and/or captured by an elite

**Collective action theory:** any group of individuals seeking to provide a public good efficiently finds it difficult due to free riding behavior and difficult determination of the optimal group size

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may not reveal the information to the principal (16). The agent is able therefore to engage in corrupt acts without the latter's knowledge. Considering their self-interest, agents decide whether to get involved in corrupt activities on the basis of available opportunities and incentives. The latter can be categorized into expected gross gain of the corrupt act, the probability of being caught, and the size of the penalty if the agent is detected and convicted (16–18). The principal agent-based literature, and the institutions recommending it, focused therefore on (*a*) measures to reduce corruption opportunities through economic liberalization and deregulation, thus reducing public servants' discretion (19, 20), and (*b*) ways to affect the incentive structure such as increasing public officials' salaries (to increase their motivation to act on behalf of the principal while at the same time increasing the costs of being convicted), increasing penalties for corrupt acts, and improving accountability and transparency to increase the likelihood of exposing corrupt practices (13, 19, 20).

The literature on corruption has noted that states are often predatory (21) and that in those states there might not be principals interested in controlling corruption (20). Hence, the principal-agent approach to corruption analysis and development of anti-corruption policies might not be as useful as initially thought in the case of those states. The classification of states according to their governance regimes and prevalence of corruption carried out by political scientists shows that only a minority of countries are in a condition that could be described as universalistic social systems—in which all citizens are treated equally by the state—and have limited corruption (10, 18, 19). At the other extreme, there are countries with particularistic systems of power—where people are not treated equally—and corruption is the norm (systemic corruption), rather than a deviation from the standard noncorrupt behavior implied by the earlier definitions of corruption (14, 22, 23). Some political scientists have argued that when corruption is systemic, it is best analyzed through the lens of collective action theory rather than that of the principal-agent theory (10, 19, 20, 24). The first-order problem of corruption as a collective action issue concerns free riding. Given that addressing corruption is very difficult, can be dangerous, and can also generate significant costs for individuals, those who doubt that others will also make sacrifices are unlikely to take action to reduce corruption, preferring to free-ride on those who might act (24). In societies experiencing high levels of corruption, institutional change such as reducing corruption generates a second-order problem for individuals with four options: (*a*) full cooperation (not acting corruptly and reporting it); (*b*) hypocritical cooperation (acting corruptly but reporting misconduct); (*c*) private cooperation (not being corrupt and abstaining from reporting it); and (*d*) full defection (acting corruptly and not reporting it) (25). Acting corruptly has greater benefits than acting fairly in the presence of systemic corruption (26).

There is ongoing debate about whether collective action theory and principal-agent theory are complementary in the analysis of corruption and anti-corruption (27–29). The proponents of the use of collective action theory to address systemic corruption do stress that principal-agent theory can be usefully applied in contexts where corruption is not systemic but question its applicability to systemic corruption (28). The proponents of the view that the two theories may be complementary also argue that there are also other theoretical perspectives on corruption that should not be discarded (29). The empirical analysis of anti-corruption initiatives discussed in the next section highlights several initiatives arising from the application of the principal-agent theory that do not appear to have been effective. Therefore, in the sections that follow, we highlight some situations in which the application of the principal-agent theory might not be appropriate. We do that to exemplify why the application of that theory (which is also probably the most familiar to the readers) may not be appropriate in the case of systemic corruption. However, we do not imply that the principal-agent theory is categorically inapplicable or, alternatively, that the two theories are complementary. To arrive at a firmer conclusion, the theoretical debate noted above needs to

be developed further, and the possibility of developing anti-corruption initiatives based on the integration of the two theories has to be further explored and eventually tested. That is beyond the scope of this review.

### 3. ANTI-CORRUPTION POLICIES AND THEIR EFFECTIVENESS

There is widespread agreement that many anti-corruption initiatives that have been promoted by international organizations during recent decades have not been effective (10, 11, 18, 20, 21–23). Therefore, there is a need to consider the evidence about what has worked for the countries that have historically been effective in reducing corruption (30) and to also develop new strategies (31).

The structural conditions of a society—such as life expectancy and education levels—which are captured by the Human Development Index and Internet users as percentage of the population explain between half and three-quarters of the variation in the control of corruption in an econometric analysis (14). Those path-dependent values imply that the remaining variation in the control of corruption depends on nonstructural factors that can be affected by anti-corruption policies (14). The anti-corruption policies that have drawn most directly on the principal-agent theory, such as reforming the civil service, have not been very effective in reducing systemic corruption (32, 33). Other anti-corruption measures that have been widely recommended are freedom of information laws, anti-corruption agencies, and ombudsman offices. Again, econometric evidence indicates that those measures have not been effective in addressing systemic corruption (14), and that freedom of information laws appear to increase perceived corruption when implemented in countries with a higher degree of media freedom, presence of non-governmental organization activism, and political competition (34). Let us turn therefore to the institutional characteristics, policies, and strategies for which there is some evidence about their effectiveness against corruption, or that have more recently been proposed for adoption.

There is not a single, best practice set of anti-corruption policies and strategies that different scholars agree on. However, one view on which many scholars do agree is that anti-corruption policies need to be tailored to the specific situation of a country, and in some cases to the specific conditions of different areas within a country (31). From a strategic perspective, the view that corruption is a collective action problem implies that there is a need to bring about the expectation that other actors will behave in a noncorrupt way rather than corruptly (23). As some researchers note (23), that change requires significant structural changes across the whole public service. However, there is the view that, although increasing social trust is a worthwhile goal, changing behavioral expectations in the context of fragile states is a significant challenge and that the literature has not explained how it can be achieved (35). This problem has been acknowledged by research noting that the best opportunities for anti-corruption initiatives are not found in the countries with the lowest governance scores (neo-patrimonial countries ranked as Not Free by Freedom House) but in the intermediate ones, defined as Competitive Particularistic (countries ranked as Free or Partly Free by Freedom House, and having a Control of Corruption Index between 3.3 and 6.6) (14).

Supporting education has been proposed as a key strategy to impact at the structural level to generate collective action to address corruption (24, 36), particularly because it contributes to deeper democratization by enabling citizens to demand justice and better government. However, a question that remains to be clarified is what new or different education activities should be supported given that most (if not all) countries have ongoing education programs, often supported by development aid.

At the policy level, detailed recommendations for anti-corruption policies that have been shown to be effective, through qualitative and quantitative analyses, have been put forward to

constrain corrupt activities and to reduce opportunities for corruption (10, 36). Policies that increase constraints include support for judicial independence, strengthening of civil society, freedom of the press, and more empowered citizens (through more IT investment in education and training of educators, and Internet freedom) (14). Policies that reduce opportunities for corruption include (a) measures to address ethnic fractionalization, such as equal access to schooling; (b) policies that address the extent and transparency of administrative decisions; (c) public spending targeted to health, education, and innovation, with infrastructure spending (which is often the source of significant corruption opportunities) funded through private-public partnerships; (d) simplification of taxation and its collection; and (e) private management of natural resources with public share of revenues established with public consultation, and transparency of related public spending (14).

After considering policies for which there is evidence of effectiveness, it is useful to look at factors that could constrain their implementation. Culture has often been seen as a significant cause of corruption and a factor that constrains the implementation of anti-corruption policies, particularly within the anthropological and economics literature, but that view is not supported by empirical evidence (36). A case in point is Georgia, which was said to have a culture of corruption but then made significant progress in reducing it when a new government, led by politicians with a strong anti-corruption agenda, took power in 2004 (37). One of the lessons learned from the case of Georgia is that no country appeared to have made significant progress with piecemeal reforms (37). A question that would need to be clarified, however, is what constitutes a piecemeal reform. For example, does it mean that all the above-mentioned policies to increase constraints on, and reduce opportunities for, corruption need to be implemented, at the same time or in a sequence? As we have found no clear evidence that they all need to be implemented (at the same time or in a sequence), we consider the relevant ones when addressing anti-corruption policies in the ERM sectors.

Finally, improvement in country-level performance in addressing corruption does not necessarily mean that illegality in all sectors, including ERM ones, is automatically eliminated or reduced. For example, Georgia still has significant illegality in the forestry sector despite its progress in reducing corruption (<https://www.ganintegrity.com/portal/country-profiles/georgia/>).

## 4. CORRUPTION IN THE ENVIRONMENTAL AND RESOURCE MANAGEMENT SECTORS

Let us now turn to addressing in detail corruption in ERM. We start with the extractive industries, given their significant weight in the economies of many countries.

### 4.1. Extractive Industries

Extractive industries, which include mining, oil and gas extraction, and forestry in some studies, as discussed below, provide such a significant contribution to the economy of many countries that 47 of them were classified as resource dependent (defined as having average revenues or exports of at least 20% of total fiscal or total export revenues) during the period 2006–2010 (38). The sheer value of those resources presents significant opportunities (i.e., resource rents) for corruption. The activities of industrial (as opposed to artisanal) extractive industries are concentrated in terms of the value of each concession and lend themselves to grand corruption. The latter refers to the payment of large bribes, as opposed to petty corruption, which involves small payments such as a bribe by poachers to a park ranger to hunt wildlife for personal consumption.

The opportunities for corruption in the extractive industries are so significant that we consider whether these industries increase corruption. An econometric study covering 124 countries over

the period 1980–2004 found that the presence of natural resources (which included oil, minerals, and forestry) increased corruption in relatively less democratic countries (39). A study focusing on 29 sub-Saharan countries during the period 1985–2007 reached a similar conclusion (40). Interestingly, in that study higher rents are associated with a lower likelihood of internal conflicts in less democratic countries because autocratic elites are able to quell the masses through increased spending (40). But, not all extractive commodities appear to have the same effects. Fuel exports unambiguously increased corruption over the period 1998–2002 (41). However, nonfuel mineral exports increased corruption only in poorer countries, especially those that exported high-value minerals such as diamonds and gold, whereas those exports reduced corruption in richer countries (41). It is not clear why different commodity markets have different effects. It has been hypothesized that high-value minerals promote more corruption because they are easier to smuggle, and the rents they generate are more concentrated (41). However, smuggling is an illegal activity rather than a corrupt one, unless corruption is involved in smuggling. In any case, evidence about the relative amounts of precious minerals being smuggled is not presented in the latter study. In relation to rents, fuels also generate significant rents that are highly concentrated.

The aggregate costs of corruption associated with extractive industries are unknown due to the hidden nature of corruption itself. However, a corruption case being considered by a court in Milan (42) exemplifies the order of magnitude of corruption affecting this sector. The oil companies Shell and ENI allegedly paid bribes worth approximately \$1.1 billion to a Nigerian minister—who in turn paid the then president and other ministers—to obtain fiscally advantageous terms for an oil extraction contract (43). The terms are so advantageous that Nigeria would lose an estimated \$5.86 billion in revenues (43), some 30% more than the combined 2019 national budgetary allocations to education (\$1.7 billion) and health (\$2.43 billion). The social implications of this revenue loss are obvious if one considers that in 2018, Nigeria became the country with the highest poverty headcount in the world as a result of the continuing growth of headcount poverty in Nigeria itself combined with a significant decrease in India (44).

The Nigerian case demonstrates how the approval stage of contracts is a particularly significant step at risk of corruption in the extractive industries sector. Therefore, it has recently attracted increasing attention (45), compensating for the outsized focus that had been devoted to the revenues aspect, which was almost the sole focus of the Extractive Industries Transparency Initiative (EITI) when it was conceived, and which we consider in Section 5. The Nigerian corruption case also exemplifies how in a situation of systemic corruption the principal-agent theory might not necessarily apply: In approving the contract with Shell and ENI, the ministers (principals) acted against the advice of the civil servants (agents), who considered the oil deal to be against the public interest (43).

## 4.2. Irrigation

Analyzing and exposing the characteristics of systemic corruption is a difficult research task due to the complex and secretive nature of corruption. One of the most in-depth analyses of systemic corruption in the context of ERM is Robert Wade's 1980s classic study of irrigation management in India (46, 47). The corruption system described involves several hierarchical levels of engineers and reaches up to politicians, and it significantly affects the efficiency of the irrigation system in the state of Andhra Pradesh (46). To understand the nature of systemic corruption, it is useful to consider in some detail this system by following Wade's description (46).

The engineers extract bribes from contractors who build and maintain irrigation infrastructure in return for awarding the contracts and ensuring that the contractors are able to profit from those contracts by delivering substandard infrastructure. The engineers also extract payments from farmers (who are due to receive water) by issuing veiled threats of delays in (or total lack of) the

provision of water to irrigate the crops. They are also in a position to extract bribes in exchange for the provision of water from farmers whose land is not formally included in the irrigation scheme and who, therefore, receive the water illegally. The system is vertically integrated through the control that each level (from the political through to the administrative ones) has over the appointment and transfer of personnel. To be appointed to a certain position in an irrigation area, an engineer has to pay a certain amount to the higher-level engineer who is in charge of making the appointment. The sum to be paid to the appointing official is related to the (relatively well-known) income from bribes that one can raise in the specific area over the period of the appointment. For each position, there may be several interested engineers who have to offer to pay the appointing official more than the others to win the job. Those offers include an appropriate initial amount of money, which they have to determine by also taking into account that during the period of the posting they will face further demands of funds from the appointing official. The amounts requested by the appointing officials are obviously constrained by the amounts that the engineers can raise during the posting. However, the level of bribes requested by the engineers from the contractors and the farmers is constrained by the capacity and willingness of the latter to pay. If an engineer sought to extract much more than the accepted level of bribes that has developed over time, he may be faced with complaints made by the contractors to higher-level engineers and politicians, and by farmers to the local politician. The bribes that farmers pay as a proportion of their income is not significant, and does not affect their willingness and capacity to be involved in farming activities. But the total amount of bribes that an engineer can extract from contractors and farmers can be as much as five to ten times his annual salary.

The politicians and engineers resist pressures to increase over time the charges that users pay for water because an increase in charges might reduce water users' willingness to pay the usual level of bribes, which in turn results in lack of appropriate investment in the irrigation system (46, 47). The corruption system originally described for irrigation in Andhra Pradesh was also found to apply to the departments of Agriculture, Forestry, and Soil Conservation in Andhra Pradesh and other states (47). Rent-seeking in the irrigation sector was also described in the same period for Bangladesh, Indonesia, Nepal, Philippines, South Korea, Thailand, and the United States (48). In the words of the author, rent-seeking

distorts investment decisions, the design and operation of irrigation systems, and patterns of water use. The consequences are inefficient, inequitable, fiscally disastrous, wasteful of increasingly scarce water, and environmentally harmful. While the rent-seeking phenomenon is legendary in public irrigation systems in the United States it is being underemphasized in the rest of the world. (48, p. 37)

Insufficient attention continued to be devoted to the problem of corruption in the irrigation sector for decades, to the point that it was argued by a long-term practitioner that lack of engagement with the topic might even be intentional, given that national and international professionals get caught in the complex conflicts between the formal policy objectives and hidden interests, and tend to resort to rent-seeking themselves (49). Those statements come from decades of professional involvement in the sector. But even if one considered them somewhat speculative, recent evidence does indicate that systemic corruption in the irrigation sector has not seen many changes in India (50) and is present in Indonesia (51).

### 4.3. Agriculture

Wade (47) provides some general-level information to extend to agriculture, among other sectors, the model of systemic corruption developed for the irrigation sector, and its impacts on states'



capacity to promote development. Other research provides further details about the pervasiveness of corruption in the agriculture sector and its various impacts. A theoretical model—which includes officials of the credit agency, informal moneylenders, and farmers—shows that a reduction in the formal interest rate and/or increase in the price of the product may result in an increase of the equilibrium informal interest rate bribing rate (52). Applied case studies have been used to provide more in-depth analysis of the corruption-agriculture nexus and its various impacts.

A multidisciplinary study of agricultural sites in Kenya's Central Highlands shows that collective action problems linked to corruption perceptions play a role in undermining farmer involvement in Soil Conservation Committees (53). Farmers blamed decreasing agricultural productivity on corruption reducing other farmers' work ethic, rather than on soil erosion or poor soil fertility. Moreover, pastoralists' bribery of police and magistrates to access land for herding can contribute to violent conflict between farmers and pastoralists, according to a political ecology study in Tanzania's Kilosa District (54). The loss of trust in authorities that ensued in the Kilosa case because of corruption meant some actors engaged in killings as a way to solve land access problems. In Malawi, corruption was the *modus operandi* of a criminal network focused on fertilizer subsidies that included chiefs, public officials, politicians, coupon printers, businessmen, and truck drivers (55). Corruption undermined the functioning of the fertilizer scheme, such that the poorer farmers meant to benefit from it had difficulties doing so. Corruption also affects the agriculture-climate change nexus as demonstrated by the case of southern Benin, where small farmers' mistrust of local government, due in part to perceptions of corruption, led to challenges in implementing government-led climate change adaptation measures (56).

At the macro level, the existence of politically powerful special interest groups who apply their political and financial strength to influence government policies contributes to agriculturally dependent economies growing less rapidly than more industrialized or service-oriented economies (57). The study, a quantitative analysis of cross-sectional data for 20 Central and Eastern European and Central Asian economies, shows a statistically significant relationship between corruption and natural resource abundance when the latter is measured as the share of the labor force employed in agriculture (57).

Corruption in the agriculture sector can also impact the forestry sector, as noted below in the context of a broader discussion on corruption in forestry.

#### 4.4. Forestry

Since at least the 1980s, there has been increased awareness that forestry has historically operated within a corrupt environment (58, 59). It was probably through the Barnett Inquiry into corruption in the logging industry in Papua New Guinea (60) that the issue achieved global prominence. The judicial inquiry was ordered by the Prime Minister of Papua New Guinea to investigate the operations of the timber industry in the country. It exposed extensive corruption and other forms of illegality in the sector. Then, it was highlighted that corruption appeared to be facilitating illegal logging (61), a practice that affects many countries (62) and has significant negative environmental impacts given that in several countries more than 50% of the harvested timber is of illegal origin and increasingly derived from illegal land clearing (63).

A study focused on a broader assessment of the impacts of corruption on biodiversity attempted to quantitatively assess at the global level the relationship between forest loss and corruption (64). That analysis (using data for the period 1990–1995) found that total forest cover (which included plantations) was correlated with corruption; however, natural forest cover was not. The authors explain these findings by suggesting that change in total forest cover was driven by an increase in plantations in the less corrupt, wealthier countries, and that logging is also used as an economic

development policy (64), which could mask the effects of corruption on natural forests. However, those findings were shown not to be robust. Corruption did not have explanatory power when potential missing variables (which included anthropogenic and biophysical factors) were included, the estimation used changes rather than levels in the variables, and additional data points from the same sources were included (65). It is therefore important to develop clear causal models of how corruption affects natural resources; otherwise, significant control variables could be missed (65). The study also argues that there are different forms of corruption that may need to be considered and that they could have negative, positive, or no impacts on natural resources (65).

A causal theoretical model, which was then tested empirically using panel data of agricultural land expansion (equivalent to deforestation) in low- and middle-income tropical countries over the period 1960–1999, found that increased corruption and resource dependency directly promoted land conversion (66). Whereas the higher terms of trade (which increase the value of agricultural exports) tend to result in reduced land expansion, the effect declines significantly in the more corrupt countries, possibly because the additional foreign exchange earnings are captured by corrupt officials, thus lowering the private agents' incentives to reduce deforestation (66). The impact of corruption on forests via agricultural expansion has been corroborated by another theoretical model tested empirically with data from nine Latin American countries over the period 1985–2000 (67). The more corrupt governments provide larger amounts of agricultural subsidies, which in turn depress agricultural productivity, thus promoting excessive deforestation (67).

Corruption affects the industrial exploitation of forests and small-scale forest management in several ways. In industrial forestry, corruption has affected the zoning of forested land into conservation and logging land uses (68) and the allocation of logging concessions in return of financial and/or political favors (51, 52). Logging concessionaires, even if they had obtained the concession legally without corruption, have an incentive to bribe logging inspectors to harvest more than allowed, to remove only the highest valued trees (in contravention of the forest management plan), and not to implement fully environmentally sensitive logging requirements, as demonstrated through a theoretical analysis coupled with a numerical simulation (69). Examples of the ways in which corruption weakens the monitoring and enforcement of forestry regulations include corrupt forestry officials' lack of reporting of acts in breach of the regulations (68), and documents might go missing at the stage of prosecution as a result of corrupt exchanges (70). Corruption not only facilitates forest degradation and deforestation by industrial-scale activities, it can also stymie the rehabilitation of degraded forests or deforested areas by impacting negatively the use of funds that are meant to support those activities (71).

That corruption in many countries is systemic means that it also affects small-scale forest extraction activities, and it led Robbins (72) to call it the rotten institution. He found that in India the village elites bribe forestry officials who in return allow them to harvest the forest beyond the allowed amounts. Small-scale illegal logging has been found to be facilitated by corruption in numerous other countries in Africa (73, 74), Asia (75), and Latin America (76).

#### 4.5. Fisheries

Global capture fisheries are well managed in regions with good governance, but tend to be in poor health in regions with poor governance (77). Several governance factors affect fisheries including whether they are open access (77) and the extent of illegal exploitation (78). The annual illegal and unreported catch over the period from 1980 to 2003 was in the range of 11 to 26 million tonnes, according to a global assessment that covered 54 countries, 15 high seas zones, and 292

case study fisheries, accounting for approximately 46% of the reported total marine catch (78). The illegal and unreported catch amounted to an average 18% of the reported catch over the most recent period assessed (2000–2003) in that study. Extensive illegal harvesting negatively impacts the health of fish populations and, together with unreported catch, also has significantly negative financial implications. The illegal and unreported catch was in fact valued at between \$10 and 23.5 billion annually (78). Countries and fishing zones were impacted to different degrees, with the Eastern Central Atlantic area (which includes countries from Morocco to Angola) being the most affected with an average of 37% (78). Illegal and unreported catches correlated with an average of four World Bank governance indicators, which included Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption (78). It is notable that a more recent study focused on Mexico estimated that the illegal and unreported catch during the period 1950–2010 was almost twice as much as the reported catch (79), indicating that, at least for some countries, the illegality situation could be even worse than indicated by the earlier study.

Corruption in the industrial fisheries sector has also been discussed in relation to the small Pacific Island states, which rely significantly on revenues from foreign vessels active in their exclusive economic zones. Corruption has been rumored to take place in the issuing of fishing licenses and in the negotiation of fishing access agreements (80) but there is a lack of evidence, at least in the case of Pacific Island states. In those states, corruption in industrial fisheries is said to take place as the result of single individuals (e.g., ministers) being given full control and discretionary power in the negotiation of those agreements and issuing of licenses (80). Corruption is also said to occur in West Africa's industrial fisheries with the involvement of European, Russian, and Asian fishing firms supported by their home governments (81). In this case, too, there is uncertainty about the extent of corruption, but there appears to be more circumstantial evidence compared to the case of the Pacific Islands.

Small-scale fisheries are also affected by corruption. Coastal fisheries in South Africa are a common pool resource exploited by many small-scale fishers on the basis of national regulations, which are to be enforced by some 400 inspectors located along the coast (82). Interviews with a sample of inspectors have shown that bribery is commonplace. Inspectors take bribes and, in return, they warn fisherfolks about inspections and/or implement inadequate enforcement actions, which can result in no, or lower than expected, penalties (82). As corruption is widespread, if inspectors did not take bribes, members of the judiciary would take them to find the fisherfolks not guilty; therefore, inspectors face a lack of incentives to avoid taking bribes (82), which is a clear example of the collective action problem highlighted by the political science studies discussed above.

Widespread corruption has also been documented in the enforcement of regulations of the co-managed fishery of Lake Victoria, which spans Kenya, Tanzania, and Uganda (83). The interviewed boat owners allege that leaders of Beach Management Units (the co-management organizations), fisheries staff, policemen, and the judiciary take bribes in return for lenient or no enforcement in relation to many aspects of the fishery, including allowing illegal fishing to take place and to return gear that had been seized (83). Those findings are similar to those of other research focused on the Kenyan part of the same fishery (84). Importantly, the introduction of co-management in the fishery coincided with an increase in unsustainable fishing practices, and a concurrent decline in fish stocks (84). The implication is that the devolution of natural resource management to local institutions does not necessarily lead to sustainable resource management in a context of widespread corruption (84).

We have seen that corruption contributes to the expansion of agriculture into forests, facilitates a range of illegal activities that degrade forests and fish populations, and affects even the sustainable commodity chain of beef (85). In turn, biodiversity is negatively affected by agricultural, pastoral,

and forestry activities (86) as well as fishing practices (87). There are several other ways in which corruption impacts biodiversity.

#### 4.6. Conservation

The Human Footprint is a composite index (based on maps at 1 km<sup>2</sup> resolution) of eight human pressures on the environment: built environments, crop lands, pasture lands, population density, night lights, railways, major roadways, and navigable waterways (88). Over the period 1993–2009, the global human population increased by 23% and the economy by 153%, while the human footprint increased by 9% (88). The increased pressure was distributed over 75% of the land surface, and it intensified particularly in areas suitable for crops and with high biodiversity (88). Those pressures were inversely proportional to national income levels, human development (a composite index including health and education), and control of corruption (88).

One way to control the increase of the human footprint on the environment is to establish PAs. They cover approximately 14.7% of the terrestrial land area (89) and are effective in protecting biodiversity (90). However, terrestrial PAs face several threats, which were identified by a global survey that covered 1,961 PAs in 149 countries (91). The top 10 threats ranked in order of frequency are hunting and collecting terrestrial animals, recreational activities, fire, invasive species, gathering of plants, housing and urban areas, livestock farming, logging and wood harvesting, fishing and harvesting of aquatic resources, and habitat alteration. The likelihood of PAs having multiple threats is higher in countries with lower levels of control of corruption and lower human development, whereas threats are lower for the more remote PAs (91).

The significance of corruption for the conservation effectiveness of PAs is corroborated by a regression analysis covering 71 countries, which used satellite data for the period 2000–2012 and nearest-neighbor matching to estimate avoided deforestation of PAs (92). PAs are more effective in countries with lower corruption and higher levels of protection of property rights. Given that corruption affects the management of PAs, the identification of conservation priorities for the establishment of PAs should account for corruption risks. For instance, including a measure of corruption in the identification of global conservation priorities for mammals does affect the choice of the areas, but some areas are so important for conservation purposes that they would be selected even after taking into account the increased cost of conservation due to leakage of funds through corruption (93). However, other areas that might be cost effective for conservation purposes would not be included due to their increased costs resulting from corruption (93).

Wildlife, which is found within and without PAs, is also negatively affected by corruption. Elephants, one of the most charismatic species, are being illegally killed inside and outside PAs for their ivory, resulting in a 30% decline in their populations in Africa (94). During the period 2002–2017, the annual poaching rates across 53 sites in Africa were strongly correlated to demand for ivory in China, but between-country and between-sites poaching rates were positively correlated to indicators of corruption and poverty (95).

The illegal wildlife trade is facilitated by corrupt activities often involving government officials at all levels, from the park ranger who provides information about the schedule of the patrols to the poachers, to high-level security officers who protect the traders and allow cross-border trade, and even the judges and politicians, as described in detail through an ethnographic study on Uganda, Morocco, Russia, and China (96). The case of a wildlife conservation area in India also highlights how pervasive corruption can be in supporting the illicit use of resources (97). Given the restrictions on resource use, all those involved appear to prefer the current system, making the identifications of options to reduce the illicit use of resources and corruption extremely challenging (97).

#### 4.7. Summary

We have seen that corruption is widespread across the ERM sectors analyzed, and there is also evidence that it is systemic. The corruption system was revealed in detail for the irrigation system in India, and that model was also found to be relevant to other ERM sectors in that country. The corruption system seems to continue, even if it might present itself with some variants (50). Many of the studies considered for the various sectors are not able to show the inner and systemic working of the corruption system to the extent that Wade (46) does. Some, such as in the case of the small-scale fisheries, do, however, highlight that it is not just the odd “rotten apple” who is involved in corruption. Rather, many officials from various government departments and the judiciary are corrupt, which does tend to indicate the presence of systemic corruption even if the system per se is not fully revealed.

That so far only a brief mention has been made of the livestock sector does not mean that it is mostly free of corruption. The livestock sector had the lowest number of references found through our literature search on corruption in the various ERM sectors. But it cannot be excluded that it is simply due to lack of interest on corruption among researchers in the sector. In fact, one of the most egregious examples of corruption analyzed in the ERM sectors is that of Juan Vicente Gómez, general, president and de facto ruler of Venezuela between 1908 and 1935 (98). The cattle business enterprises he and his political allies established were critical to officials’ support for him and in the establishment of his regime’s authority. Corruption was a key element in the operations of those enterprises and the cattle trade, and therefore a key factor in state formation (98).

On the basis of the research discussed in this section, we can see that the pervasiveness of corruption in many developing countries highlighted in recent years by political scientists does apply to the ERM sectors considered here. It is also clear that corruption in the ERM sectors has negative economic and financial (and therefore social) and environmental impacts. For instance, corruption in the extractive industries deprives states of billions of dollars in revenues that could be used to fund government expenditure in all sectors, including education, environment, health, and infrastructure. Corruption in the irrigation sector deprives farmers of a share of their income through the payment of bribes and, by reducing the efficiency of irrigation, it has negative impacts on crop production (for the farmers who have legally recognized rights to water). Negative environmental impacts arise from a range of factors, including unsustainable resource exploitation in forestry and fisheries, illegal expansion of agriculture into forests, wildlife poaching, and mismanagement of PAs. The most relevant question therefore is no longer whether corruption should be addressed because it has negative impacts on these sectors (8). Rather, one must consider the anti-corruption policies that could be implemented in the ERM sectors.

### 5. ANTI-CORRUPTION POLICIES IN ENVIRONMENTAL AND RESOURCE MANAGEMENT

The anti-corruption literature considered in Section 3 suggests many policies that are beyond the scope of interventions in the ERM sectors, given that they involve a whole-of-government focus, or focus on specific sectors other than ERM ones (such as support for judicial independence). There are, however, some policies that are also relevant to the focus of this review, particularly, (a) policies that address the extent and transparency of administrative decisions; (b) private management of natural resources with public shares of revenues established with public consultation, and transparency of related public spending; (c) simplification of taxation and its collection; (d) strengthening of civil society; and (e) freedom of the press. Rather than considering them individually, we refer to them in the context of the analysis of the policies that have been implemented or proposed in the ERM sectors addressed in this review.

Several anti-corruption measures have been proposed in the ERM sectors, but there is very limited evidence in relation to the effectiveness of measures that have been actually implemented. The most significant one is the EITI. EITI is the global standard to promote the open and accountable management of oil, gas, and mineral resources (<https://eiti.org/who-we-are>). The objective of the standard is to promote the open and accountable management of oil, gas, and mineral resources (with timber included in some countries more recently), thus contributing to curb corruption in those sectors. The 52 member countries are required to disclose information along the value chain from the point of extraction, to how revenues make their way through the government, and how they benefit the public (<https://eiti.org/who-we-are>). EITI's objective encompasses therefore more than the reduction of corruption as it could contribute to address other illegal activities such as fraud. However, the focus on achieving its objective through increased transparency in the management of revenues clearly places the initiative within the realm of anti-corruption measures given the prominent role that transparency has achieved in this arena (99).

The EITI focused on disclosure (i.e., transparency) of data on revenues from extractive industries raised by governments until 2013, when the standard was modified to include further disclosure requirements for state-owned companies, transit payments, and social expenditures, as well as disaggregated reporting and improved auditing mechanisms (100).

Over the period 2006–2013, membership of the EITI resulted in improved overall aggregate data disclosure, according to an analysis that used interrupted time series and panel data methods (100). However, membership of the EITI was not statistically significant in the regression analysis that had corruption [measured with the Transparency International's Corruption Perception Index (CPI)] as the dependent variable (100). The author questions therefore the sole focus of the EITI (at least in the period covered) on data transparency, which is only one of three aspects of transparency, the other two being media openness and institutional transparency (100). However, another study that used unbalanced panel data and random effects estimation to assess the effects of the EITI on corruption (also measured using the CPI, but over the period 2002–2011) finds that membership of the EITI did not result in an increase in corruption over time, whereas non-member countries experienced increases in corruption (101). Further research comparing the methods, independent variables, and time periods used by the two studies would be needed to derive more definitive conclusions about EITI's effectiveness in addressing corruption. Further research would be also important before attempting to implement an initiative such as EITI in other sectors, as proposed for the fisheries sector (102).

Apart from EITI's implementation, other anti-corruption measures in the ERM sectors have been proposed but, to our best knowledge, have not been implemented, or at least there has not been research assessing their effectiveness in reducing corruption. It is useful, however, to consider the anti-corruption measures that have been proposed and how they compare with the measures that have been found to be effective in reducing corruption.

Research on irrigation (47) had suggested the importance of understanding the systemic characteristics of corruption in each context/country to develop appropriate policies well before the more recent renewed call emanating especially from the political science research noted in Section 3. However, that suggestion has essentially been taken up neither in the irrigation sector (49) nor in the other sectors. There is perhaps one recent exception in irrigation that reassessed the system described by Wade (50), and one in forestry (72), although the latter did not analyze the corruption system as in depth as Wade did.

The importance of the analysis of the system of corruption is exemplified by the fact that it enabled Wade to draw a clear analysis of some of the within-sector causes of corruption (i.e., lack of user participation as well as a certain degree of control in irrigation projects, scarcity of water resources, and substantial differences in education and status between irrigation department

engineers and farmers) and the causes outside the sector (i.e., the political system that has created local centers of patronage that contribute to pressure toward corruption and political control of the irrigation bureaucracy through transfers of departmental staff) (47). The analysis of the systemic causes underpins the assessment of possible anti-corruption measures. The importance of highlighting the role of the electoral system and politicians' involvement in transfers' decisions in the case of irrigation in India points to the significant challenge involved in addressing corruption within a single sector, as there are causes outside the sector. At the same time, it makes clear that focusing on only a single sector (and often with technocratic, principal agent-based measures, as discussed next) might not be sufficient to bring about a reduction in corruption. On the positive side, sectoral political-economy analyses can shed light on potential constituencies for change.

A significant number of more recent analyses have considered anti-corruption policies rooted in the principal-agent theory. A typical anti-corruption recommendation in this mold is an increase in official salaries to maintain a well-paid and motivated work force (75). Lack of financial resources to increase salaries is a significant constraint on this policy, particularly in developing countries. But even more important is the fact that government officials might still engage in corrupt activities even if their salaries were increased, if they operate within an administration experiencing systemic corruption. Otherwise, the existence of grand corruption—which normally involves high-level government officials with high, or higher, salaries—could not be explained. Another typical principal-agent anti-corruption recommendation is to increase penalties for corruption simultaneously supported by an improved enforcement system (7). However, even if such a proposal was passed into law, in the presence of systemic corruption there is an actual lack of enforcement of the law (most often due to corruption in the enforcement agencies), often compounded by corruption in the judiciary.

The privatization of (agricultural) land (57) is an anti-corruption policy that can also be seen to belong to the principal-agent theory's armory. As public land is sold, or distributed to the rural population, politicians and bureaucrats lose control over it, which in turn results in reduced opportunities for corruption, although the process of land reform itself can be affected by corruption. Privatization can also be a controversial policy in some cases, given that citizens may prefer public ownership of certain resources (e.g., forests), or it might not be a viable option, for example in the case of offshore fisheries. An alternative to privatization is private management of natural resources with the public share of revenues established with public consultation, and transparency of related public spending, as recommended by the broader literature on corruption. It applies to mineral and oil resources (as implemented through the EITI) but it is also relevant to sectors such as forestry and fisheries. A further alternative is co-management. It has been proposed, coupled with improved enforcement, to address corruption in fisheries management (84, 103) because, apart from its livelihood benefits, it breaks the agent's (and in some case the principal's) direct control over the resource and it can improve transparency in the management of the resource. We have seen, however, that corruption also takes place in the context of co-managed fisheries.

The anti-corruption measures in the principal-agent mold discussed above, and those in **Table 1**, are obviously dependent on the willingness of the principal (the politicians) as well as the agent (bureaucrats, who also have the role of advising politicians on reform issues) to actually implement them.

The simplification of taxation and its collection, which has been highlighted as an effective policy by the broader anti-corruption literature (14), is an issue that had been addressed in the context of ERM some four decades ago (109). However, it seems to have received relatively limited attention in more recent decades, with some exceptions (110). Although many of the reforms that may be required by a taxation system might be outside ERM sectors, research and reforms within

**Table 1 Selected anti-corruption measures based on principal-agent theory**

Measure	Sector	Reference(s)
Improve public financial management to underpin sectoral reforms	Forestry, fisheries	71, 104
Improve monitoring of enforcement agencies	Fisheries, forestry	82, 105
Strengthen law enforcement capacity and increase law enforcement	Forestry, wildlife	106, 107
Different law enforcement teams scrutinize each other to minimize collusion	Wildlife	108
Meritocratic hiring and promotion, and introduction of performance-related pay	Forestry	105

those sectors could obviously contribute to the reform of the overall system. It is useful to note a point about this anti-corruption policy which has been recently highlighted within the political science literature, which tends to emphasize political economy/collective action measures. The simplification of taxation and its collection also addresses concerns that can be seen as arising from principal-agent theory given that, for example, a complex tax collection system can present more opportunities for corruption for the agent. This points to the fact that (not all) anti-corruption measures clearly belong to either principal-agent theory or collective action theory. A further point is that some of the policies proposed from a collective action theory perspective might also be subject to the willingness of the political class in power.

The strengthening of civil society organizations with support from external donor organizations has been found to be effective by the broader literature on corruption (14). Within the literature on ERM, civil society is seen as having several possible roles in addressing corruption, which include (a) increasing accountability by scrutinizing governments' decisions in relation to the award of mining and logging concessions (7) and participating in open forums that discuss natural resource management policies and their implementation by government agencies (111), (b) contributing to improved law enforcement by participating in ad hoc committees that scrutinize the activities of government agencies (105), (c) working together with government and business organizations to improve governance outcomes (112), and (d) having increased voice to encourage elected representatives to move the profits of recreational hunting out of the hands of the elite (113). However, the actual strengthening of civil society organizations does not seem to have been addressed directly by the literature on corruption in ERM. There is therefore a need to assess the type of support required by civil society organizations to engage effectively in anti-corruption campaigns in ERM. Eventually, the effectiveness of that support and its impacts on corruption would also need to be monitored and reviewed.

Apart from civil society organizations, communities are also seen as having the potential to contribute to anti-corruption efforts, even if indirectly. Specifically, local communities could provide antipoaching intelligence beyond park boundaries (9), including information on who is paying and who is receiving bribes, which in turn would increase poachers' risk of being caught. In turn, this might decrease the poachers' willingness to continue poaching if its potential costs exceed the benefits, thus reducing payments of bribes. This obviously places this measure within the principal-agent model and raises the usual question about why principals who are corrupt would want such a measure implemented. And when there are restrictions on resource use, such as those relating to hunting or extraction of forest products, all those involved, including communities, often prefer the existing system, making the identifications of options to reduce the illicit use of resources and corruption extremely challenging (97). If there was an interest on the part of the principals to change the situation, consideration should be given in the first place to whether certain restrictions on livelihood activities are appropriate and just (as their removal would also reduce opportunities for corruption), rather than just seeing communities as potential monitors of a resource management system in which they might not have a significant stake.



Finally, to our best knowledge, the role of the press in anti-corruption does not appear to have been addressed in the ERM literature, perhaps because it is seen as outside the scope of the ERM sectors. Support for press freedom has often involved measures such as recommending whistleblower legislation and training on investigative journalism (30). However, journalists know the environment very well and are often well trained but lack secure servers to store information and publish newspapers (30). Providing access to secure servers to journalists investigating corrupt activities in ERM sectors would seem to be well within the scope of ERM donor funded programs.

## 6. IMPLICATIONS FOR RESEARCH AND POLICY

Corruption is systemic in many countries, in fact, given less than 40 are classified as universalist countries (14). Corruption extensively affects the ERM sectors, and it affects the administration of all ERM processes and management approaches. It impacts land use planning, conservation activities, the allocation of concessions for resource extraction, the use and extraction of resources, their monitoring and law enforcement. It affects industrial-scale resource management as much as it does small-scale activities on land and the sea, co-managed activities included. It would be surprising if it did not in countries where it is systemic. These effects result in significant economic, environmental, and social impacts. The question therefore is not whether corruption should be addressed in the ERM sectors, but what needs to be done to reduce it.

There is agreement in the literature that the systems of corruption specific to each country need to be understood in order to devise appropriate and targeted anti-corruption policies. Given that corruption does not affect just one sector, that it is difficult to research due to its sensitive and underground nature, and that it is therefore time consuming and expensive to research, targeted research funding from donor organizations is required, and it would be ideal if there was coordination of funding and research efforts to maximize the coverage of countries and sectors. Coordination could involve, for example, pooling of funds to research systemic corruption in several sectors, which do not necessarily need to be only ERM. In fact, research on corruption in the political system can be expected to be highly relevant, given that without politicians' involvement it is highly unlikely that corruption could continue unabated. It is obvious that external funding on political corruption can be a rather sensitive issue, and it might not be always viable. However, if local universities were supported to carry out social science research on the governance of ERM sectors, they may be able to engage in research on how corruption in politics affects ERM sectors.

We have not attempted to assess the extent of funding currently allocated to research on corruption in the ERM sectors. The above-proposed funding support for research is based on the relative lack of in-depth studies on systemic corruption. An analysis of the potential sources of funding for that research, and eventually the amount of funding available and its focus, would be a useful step in the development of funding programs. From personal experience, very few options appear to be available to interested researchers, possibly because the topic seems to be too sensitive for donors to support it. It is a challenging topic for individual researchers because it is difficult to access information, and publishing on corruption could result in being banned from a country, or worse. It is for this reason that larger, collaborative projects are required. Those research efforts would be best focused on countries where there may be more opportunities to develop anti-corruption activities. Those are essentially the countries that are listed as partly free or free in the Freedom House's index and have a Control of Corruption score between 3.3 and 6.6 (14). Countries that are "not free" are unlikely to implement reforms with external support, and countries with a corruption score above 6.6 do not have a significant corruption problem.

Country-focused studies, informed by broader reviews of corruption, would be an important way to identify anti-corruption measures specific to the local context. However, some measures

may be usefully applied across several countries. The EITI is an example of such an anti-corruption initiative. By enlisting an increasing number of countries with similar or related resources, it brings peer and market pressure to bear on individual countries, rather than relying simply on pressures from donor countries. For this reason, comparative research across countries, and across ERM sectors in different countries, could be expected to be an important source of findings on viable and, hopefully, effective anti-corruption policies.

In relation to the EITI, we have noted that it has been suggested for adoption in other sectors, such as fisheries. However, the extent to which it has been successful in reducing corruption, or avoiding its increase, is still debated. Given that the EITI standard has been modified since the earlier impact assessment studies were undertaken, a renewed focus on the assessment of its effectiveness would provide valuable information for the extractive industries, other ERM sectors, as well as the broader literature on anti-corruption due to the attention the latter pays to the relationship between increased transparency in activities such as revenue collection and expenditures and systemic corruption.

Systemic corruption means that it is driven by the existing power distribution and that all sectors are affected. Bringing about a change in the expectation that other actors will behave in a noncorrupt way rather than corruptly, a proposition put forward by the collective action perspective on anti-corruption policy, is a very complex endeavor, likely affected by many factors. Whether and how it is actually possible to significantly reduce corruption at a sectoral level needs therefore to be addressed. If corruption in one or more sectors is widespread, the expectation in another sector could be that corruption in that same sector would continue despite anti-corruption efforts because those efforts could be expected to fail in a situation of widespread systematic corruption. Due to the paucity of (assessments of) anti-corruption initiatives in ERM sectors, it would be worthwhile to review the evidence on sectoral initiatives in other sectors to inform the design of research on the development of anti-corruption measures in ERM sectors. A question related to this issue, which we have noted, is whether a piecemeal reform can be successful in addressing corruption. Are there policies that are necessary and sufficient to bring about changes in expectations about the extent of corruption? Or perhaps there are simply necessary but not sufficient policies? Are reforms taking place only in one or more sectors such as in ERM ones, but not in all government sectors, to be considered piecemeal?

An analysis of efforts in sectors beyond the ERM ones, such as health and education, would be useful to better understand opportunities for anti-corruption policies not just in the ERM sectors but for the broader literature on anti-corruption. A similar contribution to the broader anti-corruption literature would be provided by research on the effects of support to strengthen civil society organizations and communities. They have a rich history of participation in ERM sectors; therefore, a question to be addressed is how they could be further strengthened in order to have an increasingly greater role in developing ideas for, and supporting, anti-corruption initiatives.

Finally, the design and impacts of anti-corruption measures should be considered with a focus on the needs of the poor and powerless, as exemplified by the case of water services and irrigation (114). This is needed to ensure that corruption and anti-corruption research contributes as much as possible to the delivery of the SDGs.

## SUMMARY POINTS

1. Corruption affects a large majority of countries, where it is often systemic. When it is systemic, corruption is the norm in government activities rather than an exception to good governance.

2. Corruption has significant negative social and economic impacts. Therefore, a target on reducing corruption has been included in the United Nations Sustainable Development Goals.
3. Given that corruption is systemic in many countries, it is not surprising that the environmental and resource management (ERM) sectors considered in this review are also found to be significantly affected by corruption. It would have been surprising if they were not impacted.
4. Corruption in ERM sectors has significant, negative environmental and economic impacts, which in turn can be expected to have negative social impacts. These impacts clearly highlight the need to develop and implement effective anti-corruption policies.
5. Research on corruption and anti-corruption has until recently drawn to a significant extent on the principal-agent theory. Political scientists have more recently highlighted that corruption is often systemic. In that context, the principal-agent theory is not as useful because the principal is often corrupt rather than well intentioned. In those conditions, corruption is best analyzed as a collective action problem. The expectation that others will also behave corruptly needs to be changed to one that others will also behave in a noncorrupt way.
6. There is widespread agreement, particularly among political scientists, that anti-corruption policies founded on principal-agent theory have not been very effective. However, the development and testing of more effective anti-corruption policies is in its infancy.
7. There is agreement in the broader literature on corruption that a key step in the development of anti-corruption policies is the detailed analysis of the system of corruption specific to each country, which might even differ across its regions.

## FUTURE ISSUES

1. The presence of systemic corruption in the irrigation sector in India, and apparently also in the agriculture and forestry sectors, had been highlighted more than 30 years ago. However, there has been limited follow-up in terms of further research in other countries and sectors. Research on systemic corruption in ERM sectors is required to provide a solid base for the development of anti-corruption policies.
2. Researching corruption is a complex, time-consuming endeavor that requires significant funding. Donor organizations need to consider funding research targeted to countries where anti-corruption measures are more likely to be effective.
3. Research on the effectiveness of the revised standard of the Extractive Industries Transparency Initiative (EITI) has the potential to inform not only the EITI, but also its implementation in other ERM sectors, such as forestry and fisheries, as well as the broader literature on anti-corruption.
4. Future research on corruption and anti-corruption in ERM sectors would benefit from a focus on multiple sectors. This review has shown that there are often similar or related patterns of corruption in the different ERM sectors.

5. A research question to be considered is the extent to which anti-corruption policies specific to individual sectors can be effective, or whether whole-of-government reforms are required.
6. The assessment of the effectiveness of sector specific anti-corruption policies implemented in other sectors, such as in health, would contribute to research and policy development in ERM sectors.
7. The broad scope of this review, as well as its need to focus on published research, implies that it has not considered the extent to which countries have actually implemented anti-corruption reforms in the ERM sectors. Future research should seek to do a stock-take of reforms that might have been implemented, and eventually assess their effectiveness.
8. Two anti-corruption policies that have been shown to be relatively effective by the broader literature are the strengthening of civil society and the simplification of taxation and its collection. Further research on these two topics in the context of ERM sectors would contribute to knowledge for the development of anti-corruption in the ERM sectors themselves as well as in other sectors.
9. The final research topic recommended by this review is how anti-corruption policies in ERM sectors can be designed and implemented to benefit the poor as much as possible.

## DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

## AUTHOR CONTRIBUTIONS

L.T. and D.A.W. discussed the framework for the manuscript. L.T. wrote the text. D.A.W. provided (a) input to drafting parts of Section 3 relating to agriculture, fisheries, and conservation; (b) a summary of anti-corruption policies suggested in the literature on those sectors; and (c) edits to Sections 1–4.

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## LITERATURE CITED

1. United Nations. 2018. *Global cost of corruption at least 5 per cent of world gross domestic product, Secretary-General tells Security Council, citing World Economic Forum data*. Press Release SC/13493, Sept. 10. <http://www.un.org/press/en/2018/sc13493.doc.htm>
2. Gaspar V, Hagan S. 2016. *Corruption: costs and mitigation strategies*. Staff Note SDN16/05, Fisc. Aff. Dep., Legal Dep., Int. Monet. Fund, Washington, DC

3. Kaufmann D. 2005. Myths and realities of governance and corruption. In *Global Competitiveness Report 2005–2006*, ed. ME Lopez-Claros, A Schwab, K Porter, pp. 81–98. London: Palgrave Macmillan
4. Gupta S, Davoodi H, Alonso-Terme R. 1998. *Does Corruption Affect Income Inequality and Poverty?* Washington, DC: Int. Monet. Fund
5. Justesen MK, Bjørnskov C. 2014. Exploiting the poor: bureaucratic corruption and poverty in Africa. *World Dev.* 58:106–15
6. Holmberg S, Rothstein B. 2011. Dying of corruption. *Health Econ. Policy Law* 6(4):529–47
7. Kolstad I, Søreide T. 2009. Corruption in natural resource management: implications for policy makers. *Resour. Policy* 34(4):214–26
8. Ferraro P. 2005. Corruption and conservation: the need for empirical analyses. A response to Smith & Walpole. *Oryx* 39(3):257–59
9. Smith RJ, Walpole MJ. 2005. Should conservationists pay more attention to corruption? *Oryx* 39(3):251–56
10. Morse S. 2006. Is corruption bad for environmental sustainability? A cross-national analysis. *Ecol. Soc.* 11(1):22
11. Smith RJ, Ewers RM. 2007. Choice of index determines the relationship between corruption and environmental sustainability. Response to Morse. 2006. “Is Corruption Bad for Environmental Sustainability? A Cross-National Analysis.” *Ecol. Soc.* 12(1):r2
12. Organisation for Economic Co-operation and Development (OECD). 2007. *Corruption: A Glossary of International Criminal Standards*. Paris: OECD
13. Lambsdorff JG. 2007. *The Institutional Economics of Corruption and Reform: Theory, Evidence and Policy*. Cambridge, UK: Cambridge Univ. Press
14. Mungiu-Pippidi A. 2015. *The Quest for Good Governance: How Societies Develop Control of Corruption*. Cambridge, UK: Cambridge Univ. Press
15. Rotberg RI. 2018. Accomplishing anticorruption: propositions & methods. *Daedalus* 147(3):5–18
16. Klittgaard R. 1988. *Controlling Corruption*. Berkeley: Univ. Calif. Press
17. Shleifer A, Vishny M. 1993. Corruption. *Q. J. Econ.* 108(3):599–617
18. Ades A, Di Tella R. 1999. Rents, competition, and corruption. *Am. Econ. Rev.* 89(4):982–93
19. Rose-Ackerman S. 1999. *Corruption and Government: Causes, Consequences, and Reform*. Cambridge, UK: Cambridge Univ. Press
20. Fjeldstad OH, Isaksen J. 2008. *Anti-Corruption Reforms: Challenges, Effects and Limits of World Bank Support*. Washington, DC: The World Bank
21. Bardhan P. 1997. Corruption and development: a review of issues. *J. Econ. Lit.* 35(3):1320–46
22. Johnston M. 2005. *Syndromes of Corruption: Wealth, Power and Democracy*. Cambridge, UK: Cambridge Univ. Press
23. Rothstein B. 2011. Anti-corruption: the indirect “big bang” approach. *Rev. Int. Polit. Econ.* 18(2):228–50
24. Johnston M. 2014. *Corruption, Contention, and Reform: The Power of Deep Democratization*. Cambridge, UK: Cambridge Univ. Press
25. Rothstein B, Tannenbergh M. 2017. *Making development work—the quality of government approach*. SSRN Work. Pap. 3023883. <https://ssrn.com/abstract=3023883>
26. Persson A, Rothstein B, Teorell J. 2013. Why anticorruption reforms fail—systemic corruption as a collective action problem. *Governance* 26(3):449–71
27. Marquette H, Peiffer C. 2017. Grappling with the “real politics” of systemic corruption: theoretical debates versus “real-world” functions. *Governance* 31:499–514
28. Persson A, Rothstein B, Teorell J. 2019. Getting the basic nature of systemic corruption right: A reply to Marquette and Peiffer. *Governance* 32(4):799–810
29. Marquette H, Peiffer C. 2019. Thinking politically about corruption as problem-solving: A reply to Persson, Rothstein, and Teorell. *Governance* 32(4):811–820
30. Mungiu-Pippidi A. 2017. The time has come for evidence-based anticorruption. *Nat. Hum. Behav.* 1(1):0011
31. Heywood PM. 2018. Combating corruption in the twenty-first century: new approaches. *Daedalus* 147(3):83–97

32. Heeks R, Mathisen H. 2012. Understanding success and failure of anti-corruption initiatives. *Crime, Law Soc. Change* 58(5):533–49
33. Huther J, Shah A. 2000. *Anti-Corruption Policies and Programs: A Framework for Evaluation*. Washington, DC: The World Bank
34. Vádlamannati KC, Cooray A. 2017. Transparency pays? Evaluating the effects of the freedom of information laws on perceived government corruption. *J. Dev. Stud.* 53(1):116–37
35. Johnsen J. 2016. *Anti-Corruption Strategies in Fragile States: Theory and Practice in Aid Agencies*. Cheltenham, UK: Edward Elgar
36. Rothstein B. 2018. Fighting systemic corruption: the indirect strategy. *Daedalus* 147(3):35–49
37. The World Bank. 2012. *Fighting Corruption in Public Services: Chronicling Georgia's Reforms*. Washington, DC: The World Bank
38. Baungsaard T, Villafuerte M, Poplawski-Ribeiro M, Richmond C. 2012. *Fiscal Frameworks for Resource Rich Developing Countries*. Washington, DC: Int. Monet. Fund
39. Bhattacharyya S, Hodler R. 2010. Natural resources, democracy and corruption. *Eur. Econ. Rev.* 54(4):608–21
40. Arezki R, Gylfason T. 2013. Resource rents, democracy, corruption and conflict: evidence from Sub-Saharan Africa. *J. Afr. Econ.* 22(4):552–69
41. Petermann A, Guzman JI, Tilton JE. 2007. Mining and corruption. *Resour. Policy* 32:91–103
42. Padmore R. 2018. Nigeria could lose \$6bn from “corrupt” oil deal linked to fraud. *BBC News*, Nov. 26. <https://www.bbc.com/news/business-46336733>
43. Global Witness. 2018. *Take the future: Shell's scandalous deal for Nigeria's oil*. Rep. Glob. Witness, Washington, DC, Nov. 26. <https://www.globalwitness.org/en/campaigns/oil-gas-and-mining/take-the-future/>
44. Kharas H, Hamel K, Hofer M. 2018. The start of a new poverty narrative. *Brookings*, June 19. <https://www.brookings.edu/blog/future-development/2018/06/19/the-start-of-a-new-poverty-narrative/>
45. Caripis L. 2017. *Combating Corruption in Mining Approvals: Assessing the Risk in 18 Resource Rich Countries*. Berlin: Transpar. Int.
46. Wade R. 1982. The system of administrative and political corruption: canal irrigation in South India. *J. Dev. Stud.* 18(3):287–328
47. Wade R. 1985. The market for public office: why the Indian state is not better at development. *World Dev.* 13(4):467–97
48. Repetto R. 1986. *Skimming the Water: Rent-Seeking and the Performance of Public Irrigation Systems*. Washington, DC: World Resour. Inst.
49. Huppert W. 2013. Viewpoint—Rent-seeking in agricultural water management: an intentionally neglected core dimension? *Water Altern.* 6(2):265–75
50. Punjabi B. 2017. Canal bureaucracy and the corruption nexus around water in the Mumbai hinterland: questions for development and governance in Maharashtra, India. *India Rev.* 16(2):179–211
51. Suhardiman D, Mollinga PP. 2017. Institutionalized corruption in Indonesian irrigation: an analysis of the *upeti* system. *Dev. Policy Rev.* 35(S2):140–59
52. Gupta MR, Chaudhuri S. 1997. Formal credit, corruption and the informal credit market in agriculture: a theoretical analysis. *Economica* 64(254):331–43
53. Ekbom A, Knutsson P, Ovuka M. 2001. Is sustainable development based on agriculture attainable in Kenya? A multidisciplinary case study of Murang'a district. *Land Degrad. Dev.* 12(5):435–47
54. Benjaminsen TA, Maganga FP, Abdallah JM. 2009. The Kilosa killings: political ecology of a farmer-herder conflict in Tanzania. *Dev. Change* 40(3):423–45
55. Tambulasi RIC. 2009. The public sector corruption and organised crime nexus: the case of the fertiliser subsidy programme in Malawi. *Afr. Secur. Rev.* 18(4):19–31
56. Baudoin MA, Sanchez AC, Fandohan B. 2014. Small scale farmers' vulnerability to climatic changes in southern Benin: the importance of farmers' perceptions of existing institutions. *Mitig. Adapt. Strateg. Glob. Chang.* 19(8):1195–207
57. Gylfason T. 2000. Resources, agriculture, and economic growth. *Kyklos* 53:545–79

58. Robbins WG. 1985. The social context of forestry: the Pacific Northwest in the twentieth century. *West. Hist. Q.* 16(4):413–27
59. Peluso NL, Poffenberger M. 1989. Social forestry in Java: reorienting management systems. *Hum. Organ.* 48(4):333–44
60. Marshall G. 1990. The political economy of logging: the Barnett Inquiry into corruption in the Papua New Guinea timber industry. *Ecologist* 20(5):174–81
61. Callister DJ. 1999. *Corrupt and Illegal Activities in the Forestry Sector: Current Understandings, and Implications for World Bank Forest Policy*. Washington, DC: The World Bank
62. Tacconi L. 2007. *Illegal Logging: Law Enforcement, Livelihoods and the Timber Trade*. London: Earthscan
63. Hoare A. 2015. *Tackling Illegal Logging and the Related Trade*. London: Chatham House
64. Smith RJ, Muir RDJ, Walpole MJ, Balmford A, Leader-Williams N. 2003. Governance and the loss of biodiversity. *Nature* 426(6962):67–70
65. Barrett CB, Gibson CC, Hoffman B, McCubbins MD. 2006. The complex links between governance and biodiversity. *Conserv. Biol.* 20(5):1358–66
66. Barbier EB, Damania R, Léonard D. 2005. Corruption, trade and resource conversion. *J. Environ. Econ. Manag.* 50(2):276–99
67. Bulte EH, Damania R. 2007. On the gains of committing to inefficiency: corruption, deforestation and low land productivity in Latin America. *J. Environ. Econ. Manag.* 54:277–95
68. Meehan F, Tacconi L. 2017. A framework to assess the impacts of corruption on forests and prioritize responses. *Land Use Policy* 60:113–22
69. Amacher GS, Ollikainen M, Koskela E. 2012. Corruption and forest concessions. *J. Environ. Econ. Manag.* 63(1):92–104
70. Goncalves MP, Panjer M, Greenberg TS, Magrath WB. 2012. *Justice for Forests: Improving Criminal Justice Efforts to Combat Illegal Logging*. Washington, DC: The World Bank
71. Barr C, Dermawan A, Purnomo H, Komarudin H. 2010. *Financial Governance and Indonesia's Reforestation Fund during the Soeharto and Post-Soeharto Periods, 1989–2009: A Political Economic Analysis of Lessons for REDD+*. Bogor, Indones.: Cent. Int. For. Res.
72. Robbins P. 2000. The rotten institution: corruption in natural resource management. *Polit. Geogr.* 19(4):423–43
73. Siebert U, Elwert G. 2004. Combating corruption and illegal logging in Bénin, West Africa. *J. Sustain. For.* 19(1–3):239–61
74. Cerutti PO, Tacconi L, Lescuyer G, Nasi R. 2013. Cameroon's hidden harvest: commercial chainsaw logging, corruption, and livelihoods. *Soc. Nat. Resour.* 26(5):539–53
75. Smith J, Obidzinski K, Subarudi, Suramenggala I. 2003. Illegal logging, collusive corruption and fragmented governments in Kalimantan, Indonesia. *Int. For. Rev.* 5(3):293–302
76. Wells A, del Gatto F, Richards M, Pommier D, Contreras-Hermosilla A. 2007. Rural livelihoods, forest law and illegal timber trade in Honduras and Nicaragua. In *Illegal Logging: Law Enforcement, Livelihoods and the Timber Trade*, ed. L Tacconi, pp. 139–66. London: Earthscan
77. Costello C, Ovando D. 2019. Status, institutions, and prospects for global capture fisheries. *Annu. Rev. Environ. Resour.* 44(1):177–200
78. Agnew DJ, Pearce J, Pramod G, Peatman T, Watson R, et al. 2009. Estimating the worldwide extent of illegal fishing. *PLOS ONE* 4(2):e4570
79. Cisneros-Montemayor M, Cisneros-Mata MA, Harper S, Pauly D. 2013. Extent and implications of IUU catch in Mexico's marine fisheries. *Mar. Policy* 39:283–88
80. Hanich Q, Tsamenyi M. 2009. Managing fisheries and corruption in the Pacific Islands region. *Mar. Policy* 33(2):386–92
81. Standing A. 2015. Mirage of pirates: state-corporate crime in West Africa's fisheries. *State Crime J.* 4(2):175–97
82. Sundström A. 2015. Covenants with broken swords: corruption and law enforcement in governance of the commons. *Glob. Environ. Change* 31:253–62
83. Nunan F, Cepić D, Yongo E, Salehe M, Mbilingi B, et al. 2018. Compliance, corruption and co-management: how corruption fuels illegalities and undermines the legitimacy of fisheries co-management. *Int. J. Commons* 12(2):58–79

84. Etiegni CA, Irvine K, Kooy M. 2017. Playing by whose rules? Community norms and fisheries rules in selected beaches within Lake Victoria (Kenya) co-management. *Environ. Dev. Sustain.* 19(4):1557–75
85. Silvestre BS, Monteiro MS, Viana FLE, de Sousa-Filho JM. 2018. Challenges for sustainable supply chain management: when stakeholder collaboration becomes conducive to corruption. *J. Clean. Prod.* 194:766–76
86. Chaudhary A, Pfister S, Hellweg S. 2016. Spatially explicit analysis of biodiversity loss due to global agriculture, pasture and forest land use from a producer and consumer perspective. *Environ. Sci. Technol.* 50(7):3928–36
87. UN Food and Agriculture Organization (FAO), UN Environment Programme (UNEP). 2009. *Report of the FAO/UNEP Expert Meeting on Impacts of Destructive Fishing Practices, Unsustainable Fishing, and Illegal, Unreported and Unregulated (IUU) Fishing on Marine Biodiversity and Habitats*, FAO Fish. Aquac. Rep. 932, Rome, New York: FAO, UNEP. <http://www.fao.org/3/i1490e/i1490e00.pdf>
88. Venter O, Sanderson EW, Magrath A, Allan JR, Beher J, et al. 2016. Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. *Nat. Commun.* 7:12558
89. UN Environ. Progr.-World Conserv. Monit. Cent. (UNEP-WCMC), Int. Union Conserv. Nature (IUCN). 2016. *Protected Planet Report 2016: How Protected Areas Contribute to Achieving Global Targets for Biodiversity*. Cambridge, UK; Gland, Switz.: UNEP-WCMC, IUCN. [https://wdpa.s3.amazonaws.com/Protected\\_Planet\\_Reports/2445%20Global%20Protected%20Planet%202016\\_WEB.pdf](https://wdpa.s3.amazonaws.com/Protected_Planet_Reports/2445%20Global%20Protected%20Planet%202016_WEB.pdf)
90. Gray CL, Hill SLL, Newbold T, Hudson LN, Boirger L, et al. 2016. Local biodiversity is higher inside than outside terrestrial protected areas worldwide. *Nat. Commun.* 7(1):12306
91. Schulze K, Knights K, Coad L, Geldmann J, Leverington F, et al. 2018. An assessment of threats to terrestrial protected areas. *Conserv. Lett.* 11(3):e12435
92. Abman R. 2017. Rule of law and avoided deforestation from protected areas. *Ecol. Econ.* 146:282–89
93. Eklund J, Arponen A, Visconti P, Cabeza M. 2011. Governance factors in the identification of global conservation priorities for mammals. *Philos. Trans. R. Soc. B* 366:2661–69
94. Chase MJ, Schlossberg S, Griffin CR, Bouché PJC, Djene SW, et al. 2016. Continent-wide survey reveals massive decline in African savannah elephants. *PeerJ.* 4:e2354
95. Hauenstein S, Kshatriya M, Blanc J, Dormann CF, Beale CM. 2019. African elephant poaching rates correlate with local poverty, national corruption and global ivory price. *Nat. Commun.* 10:2242
96. van Uhm DP, Moreto WD. 2018. Corruption within the illegal wildlife trade: a symbiotic and antithetical enterprise. *Br. J. Criminol.* 58:864–85
97. Robbins P, McSweeney K, Chhangani AK, Rice J. 2009. Conservation as it is: illicit resource use in a wildlife reserve in India. *Hum. Ecol.* 37:559–75
98. Yarrington D. 2003. Cattle, corruption, and Venezuelan state formation during the regime of Juan Vicente Gómez. *Lat. Am. Res. Rev.* 38(2):9–33
99. Kolstad I, Wiig A. 2009. Is transparency the key to reducing corruption in resource-rich countries? *World Dev.* 37(3):521–32
100. Öge K. 2016. Which transparency matters? Compliance with anti-corruption efforts in extractive industries. *Resour. Policy* 49:41–50
101. Papyrakis E, Rieger M, Gilberthorpe E. 2017. Corruption and the Extractive Industries Transparency Initiative. *J. Dev. Stud.* 53(2):295–309
102. Standing A. 2008. *Corruption and Industrial Fishing in Africa*. Bergen, Norway: U4 Anti-Corrupt. Res. Centre, Chr. Michelsen Inst. <https://www.u4.no/publications/corruption-and-industrial-fishing-in-africa/>
103. Cross H. 2016. Displacement, disempowerment and corruption: challenges at the interface of fisheries, management and conservation in the Bijagós Archipelago, Guinea-Bissau. *Oryx* 50(4):693–701
104. Campos E, Pradhan S. 2007. *The Many Faces of Corruption*. Washington, DC: The World Bank
105. Kishor N, Damania R. 2007. Crime and justice in the garden of Eden: improving governance and reducing corruption in the forestry sector. In *The Many Faces of Corruption*, ed. E Campos, S Pradhan, pp. 89–114. Washington, DC: The World Bank
106. Rosenbaum KL. 2005. *Tools for Civil Society Action to Reduce Forest Corruption: Drawing Lessons from Transparency International*. Washington, DC: The World Bank



107. Smith RJ, Biggs D, St. John FAV, 't Sas-Rolfes M, Barrington R. 2015. Elephant conservation and corruption beyond the ivory trade. *Conserv. Biol.* 29(3):953–56
108. Walpole MJ, Smith RJ. 2005. Focusing on corruption: a reply to Ferraro and Katzner. *Oryx* 39(3):263–64
109. Repetto R, Gillis M. 1988. *Public Policies and the Misuse of Forest Resources*. Cambridge, UK: Cambridge Univ. Press
110. Karsenty A. 2010. Forest taxation regime for tropical forests: lessons from Central Africa. *Int. For. Rev.* 12(2):121–29
111. Bulkan J, Palmer J. 2008. Breaking the rings of forest corruption: steps towards better forest governance. *For. Trees Livelihoods* 18:103–31
112. Azmat F, Coghill K. 2005. Good governance and market-based reforms: a study of Bangladesh. *Int. Rev. Adm. Sci.* 71(4):625–38
113. Leader-Williams N, Baldus RD, Smith RJ. 2009. The influence of corruption on the conduct of recreational hunting. In *Recreational Hunting, Conservation and Rural Livelihoods: Science and Practice*, pp. 296–313. Oxford: Wiley-Blackwell
114. Plummer J. 2007. *Making Anti-corruption Approaches Work for the Poor: Issues for Consideration in the Development of Pro-poor Anti-corruption Strategies in Water Services and Irrigation*. Stockholm: Swed. Water House. <https://www.waterintegritynetwork.net/2007/03/05/making-anti-corruption-approaches-work-for-the-poor/>



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