Comprehending institutions more thoroughly: A complementary application of the Institutional Resource Regimes (IRR) approach and the SES Framework (SESF) in the context of pesticide use regulation in tropical agriculture

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Ruth Wiedemann *
Institute of Political Science, University of Bern, Switzerland;
Swiss Federal Institute of Aquatic Science and Technology (Eawag), Switzerland

Laura M. Herzog
Institute of Environmental Systems Research, University of Osnabrueck, Germany

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Abstract

Solving common-pool resource (CPR) problems requires adequate rules and regulations to structure and guide a sustainable use of the given CPR. To understand the different types of regulations, CPR research has elaborated analytical frameworks that aim at disentangling the diverse layers and elements of CPR settings. The most prominent ones are the Institutional Analysis and Development Framework (IAD) (Ostrom, 2005, 11-16) and the Social-Ecological System Framework (SESF) (McGinnis and Ostrom, 2014). Both consider the regulatory as well as the ecological components of a CPR problem. An analytical tool that specifically assesses the institutional setting of CPR situations is the Institutional Resource Regimes (IRR) approach by Gerber et al. (2009).

This paper examines the IRR's potential to grasp the comprehensiveness of institutions and their ability to successfully tackle the given CPR problem. It scrutinizes the IRR's complementarity to the SESF and its overall contribution to the study of institutions in CPR settings. The paper's research question is thus: *which innovative insights does the IRR contribute to the study of institutions in CPR problem settings?*

The study explores the potential of this analytical tool to specify the institutions of a CPR problem situation and to denominate their adequacy in solving the CPR problem at stake. Taking an analytical descriptive perspective, the paper first outlines the IRR's scope and analytical objectives and formulates its potential assets for the study of institutions in the context of wicked environmental problems (Rittel and Webber, 1973; Allen, 2013). A complementary application of the commonly used SESF and the IRR stresses the IRR's contributions to the study of institutions. Both frameworks are applied to the CPR problem of water contamination caused by pesticide use in Costa Rican agriculture. The study highlights the added value of integrating the IRR and the SESF when analyzing rules in a CPR problem setting: its assessment of both private property rights and public policies, its definition of different regulation modes, and its categorization of resource regimes based on the regulations' extent and coherence (Knoepfel and Nahrath, 2005). The paper closes with a critical discussion of the IRR's contributions to the study of the commons in the 21st century. Being the first application of the IRR in the context of an upper middle-income country in Latin America, this paper is a conceptual contribution to the omnipresent challenge of overcoming CPR problems.

*contact: ruth.wiedemann@ipw.unibe.ch

1 Introduction

Environmental problems are a challenge for society and policy makers since they most often have various sources, their effects appear at different levels and with different intensities and actors from diverse sectors need to be involved in its solution (Kirschke et al., 2017). One such complex environmental problem is pollution (Dowd et al., 2008; Metz, 2017). Environmental pollution is ubiquitous and humans as well as nature are faced with the consequences of soil, fresh water and air pollution through waste, chemicals and emissions. Such wicked environmental problems are difficult to solve (Allen, 2013; Metz and Ingold, 2017). To fend off the negative consequences of a resource's over-use and to protect resources and the goods they provide, one needs rules that regulate a resource's use and its protection (Ostrom, 1990, 19f., 58ff). To work out such rules, one needs to know well the problem's different causes, their effects and the dynamics between them (see Ingold et al., 2018).

This paper focuses on the understanding of an environmental CPR problem's complexity and the regulatory solutions established to solve it. Comprehending the system in which a CPR problem occurs is the prerequisite to design the appropriate policy measures that ought to manage it (Hoffmann, 2016; Pierce et al., 2017).
An analytical approach that provides a system-oriented viewpoint is the Social-Ecological System Framework (SESF) (McGinnis and Ostrom, 2014). To scrutinize the coherence of the resource management policies in place, i.e. the institutions that ought to tackle the environmental CPR problem, we further apply the Institutional Resource Regime (IRR) approach that focuses on the policy design (Gerber et al., 2009). We combine these two frameworks to assess the environmental problem on the one hand and its regulatory solutions on the other. This complementary replenishment of two analytical foci – on the system underlying a CPR problem and on the design of its user rules – allows to discern the institutions' potential in managing and solving a given environmental problem. We thus pose the following research question:

Which innovative insights does the combination of the SESF and the IRR contribute to the study of institutions in CPR problem settings?

To answer the research question, we analyze the conflicting resource uses that arise in the context of local farming in Costa Rica and determine how the institutional setting addresses these conflicting resource uses. The CPR problem at stake is the pollution of surface water due to pesticide use in agriculture. The resource use conflict arises between the *protection* of surface water for drinking water provision and intact water ecosystems and the *use* of surface water as a disposal sink for pesticides.

Natural resources such as water, air and soil provide a broad range of goods and services, such as water for drinking or domestic purposes, clean air or cultural and regulative ecosystem services like natural water filtration through soil or tourism (Reynard and Mauch, 2003). At the same time, these natural resources absorb and transport pesticides (Mateo-Sagasta et al., 2018). Pesticides affect these goods and services. To grasp this environmental problem and the resource user conflicts fully, we apply the Social-Ecological System Framework (SESF) (for more details on the IAD framework, see McGinnis and Ostrom 2014; Ostrom 2005, 11–16; and Ostrom and Schlager 2014, 267). The SESF equally emphasizes the ecological elements (the resource system and its units) and the social elements (the governance systems and the actors) of a social-ecological system (SES) in which a CPR problem occurs. The framework provides a lens through which the analyst can examine the manifold components of a SES and their dynamics in a structured way (Basurto and Ostrom, 2013; Cox, 2014; McGinnis and Ostrom, 2014; Ostrom, 2009).

The study's first step is thus the structural analysis of the conflicting uses of surface water *protection* for drinking water purposes and the aquatic ecosystem on one side and the *use* of surface water as a sink for pesticides on the other. The context in which we observe both is Costa Rica. Applying the SESF, we disentangle the social-ecological system in which these conflicts occur and shed light on the governance system's structure in which we find the institutions that aim at regulating these resource use conflicts.
In a second step, we investigate the institutional setting – which comprises laws, regulations and management plans – which ought to mediate between the resource user conflicts arising from the use of pesticides in Costa Rican agriculture.
Taking the investigation a step further, we scrutinize whether and how the conflicting uses of surface water's disposal capacity and surface water's supply capacity are regulated by the institutions. We do this using the Institutional Resources Regime (IRR) approach. The IRR allows us a) to compare the resource *protection* regulation of drinking water and aquatic ecosystems and the resource *use* regulation of surface water as an absorbing resource for pesticides and b) to determine whether existing regula-

tions balance the trade–offs between protection and use of water in the context of local farming in Costa Rica. Based on this comparison, we can identify gaps in the regulation of the resource use conflicts that inform us on the institutions' potential shortcomings (De Buren, 2015).

The social and political relevance of investigating pesticide use was emphasized by Ryan E. Galt, who claimed that *"pesticides are one of the many ghosts that haunt our modern world"* (Galt, 2007, 379). The consequences of intense pesticide use are known, however grasping the environmental problem's complexity of different causes, diverse stakeholders, and manifold impacts on nature and humans and finding adequate solutions to it remains difficult.
This research applies a considerably new approach to a matter that has been studied little in political science (for an investigation of pesticide policy implementation in Ethiopia, see Mengistie (2016); in various African states, see Loha et al. (2018) and in Vietnam, see Mol (2009)). Research does not yet address pesticide use and the determinants of the institutional setting which aims at its regulation in a concise way that would represent the topic's severity. In this paper, we investigate the solutions proposed by policy makers in Costa Rica to control pesticide use in agriculture. We assess their potential to tackle the CPR problem of water contamination and in guaranteeing human and environmental protection.
The research's contribution is the combined application of two analytical frameworks to a) identify the most relevant use conflicts between goods and services provided by the resource surface water and the application of pesticides on agricultural land and b) to study and assess the institutional mitigation options designed to address these use conflicts.

The reminder of the paper is structured as follows: after the introduction, we outline the problems pesticide use creates and argue why the application of pesticides can be considered a CPR problem. After presenting the case study, we outline the SESF's analytical objectives and formulate its potential assets for the study of institutions in the context of wicked environmental problems. Subsequently, we elaborate on the scope of the IRR approach applied to the study of CPR problems and their regulation, identifying the IRR's benefits for social science research on sustainable development. We then apply the SESF and the IRR to the case of water contamination in Costa Rica. The paper closes with a critical appraisal of combining the two frameworks to grasp complex environmental problems.

2 Conceptual and empirical assessment of a wicked CPR problem

2.1 Pesticide Use – an Ubiquitous Environmental Problem

Of the wide range of chemicals, it is the application of pesticides that is of specific concern for many governments (Mateo-Sagasta et al., 2018). Farmers continue to rely on agricultural pesticides to enhance and guarantee agricultural productivity (Hamlyn, 2015), which needs to be sustained in order to feed the growing world population (Bonner and Alavanja, 2017). Pesticides *"indiscriminately kill the bad and the good"* (Sánchez-Bayo, 2017, 79), resulting in serious negative effects for human health and the environment (Kishi, 2012; Allsop et al., 2015; Hoppin and LePrevost, 2017; Becker, 2017). A greater demand for food production and a growing need to export to foreign markets coupled with defective agricultural production lead to an increase in pesticide use (Drogui and Lafrance, 2012; Stadlinger et al., 2013; Jørs et al., 2018).

Chemicals that are applied in agriculture have multiple entryways into the human body and the environment (Weiss et al., 2016). The greatest risk related to pesticide application is exposure. Even though we are exposed to a great variety of chemical products and harmful ingredients in our daily lives, *"pesticides contribute further to the toxic burden"* (Allsop et al., 2015, 3). Pesticide exposure can be *direct*, for humans through the inhalation of the sprayed chemicals and for the environment through the spread in the environment. *Indirect* human exposure is the exposure to chemicals through the environment, e.g. through contaminated water. Another example of indirect environmental exposure are food shortages due to death of fish caused by pesticide residuals in the water. This kind of disruption of the ecosystem endangers other animals that rely on fish for their nutrition. Other entryways include the run-off into surface and groundwater bodies, aerial drift after spraying or direct intake through respiration while or after spraying (Aktar et al., 2009).
The US-American biologist Rachel Carson was the first to raise awareness for the controversy about pesticide use and its negative health and environmental effects in her book "Silent Spring" (Carlson, 1962). Her book influenced public opinion in this matter and named and shamed pesticides for having negative environmental consequences. Her research focused on the effect of pesticides on birds; today, there is a broad variety of studies observing the effects of pesticide exposure on natural

resources, humans, animals, and biodiversity in general (Berny, 2007; Diepens and Castillo, 2014; Sánchez-Bayo, 2017). Biodiversity is specifically threatened since pesticide exposure leads to the dying of birds, aquatic species, insects, and amphibians (Eyhorn et al., 2015). Either these animals' natural habitats are directly exposed – like watersheds, meadows or forests – or species suffer indirectly from exposure through the shortage of food.

Recent studies show that existing regulations regarding pesticide use lack effectiveness in different parts of the globe. In Europe, Swiss investigators found that pesticide residuals in small streams exceed legal limiting values (Spycher et al., 2019), and a study investigating 29 streams in Europe found that the European regulatory standards for pesticides were exceeded (Casado et al., 2019). Furthermore, a study of Danish pesticide regulations showed that effects of pesticide policies are limited (Pedersen and Nielsen, 2017). On the international level, two reports lament the incapacity of existing regulations to protect humans and the environment from the negative consequences of agrochemicals (OECD, 2018; UN Special Rapporteur, 2017). The report by the UN stresses the growing danger for humans and the environment induced by the dramatically increasing application of pesticides over the past years on the one side and unsafe pesticide practices on the other (UN Special Rapporteur, 2017). Pesticide use poses a challenge for regions that rely mainly on agriculture (Khan et al., 2015). These regions are often located in low– and middle–income countries (LMIC) and struggle to balance agricultural productivity with environmental protection (Rother et al., 2008; Pingali, 2012; Dabrowski et al., 2014).

2.2 Pesticide Use – a CPR Problem

The application of pesticides on crops and weed with its negative externalities for other natural resources and species can be conzeptualized as a common-pool resource (CPR) problem. CPR are natural or human-made resources comprised of a resource stock, the units of which are subtractable; that is, they reduce when being used. CPR share this characteristic of *high subtractability* with private goods. CPR users are difficult to be excluded from the use of a CPR, the criterion of *difficult exclusion* being a CPR's second characteristic (Ostrom 1990, 32; Ostrom 2000, 148; Ostrom and Walker 1994, 4ff). CPRs thus risk to be over-harvested if their use is not regulated.
Such a situation of a CPR overuse is called a CPR problem of *over-appropriation*. It concerns the allocation of the resource units appropriators want to use (Ostrom, 1990, 47). They imply a strong rivalry between users since the overuse of the resource reduces the average return other users obtain from their investment in using the resource (Villamayor-Tomas and van Laerhoven, 2014, 364).
Another type of CPR problem is the one of *provision* which refers to a resource's stock (Ostrom 1990, 47; Ostrom and Walker 1994, 9). A CPR provision problem considers on the one side CPR users' motivations to alter their consumption pattern to give the resource the chance to recover and to provide its goods. This is labelled a *demand-side* provision problem, because the resource's capacity to provide its goods and services is affected by the behavior of those demanding the provision. A CPR provision problem can also refer to the *supply-side* of provision. Here, the focus lies on users' motivation to maintain a CPR (Ostrom and Walker, 1994, 12). Ostrom and Walker (1994, 15) argue that the two types of a CPR problem – over-appropriation and provision – are interrelated: *"(...) the nature of the appropriation problem is affected by how well the provision problem is solved."*

The environmental problem of surface water pollution caused by pesticide use can be conceptualized as an over-appropriation *and* a provision CPR problem. The case study's CPR is surface water. Pesticides applied on soil can be washed off the fields through erosion and precipitation, entering the water cycle and reducing the water's quality. Less resource units in good quality are available for other users – one encounters a CPR problem of *over-appropriation*. Costa Rican farmers' conviction to apply pesticides to intensify their harvest and citizens' need for surface water in good quality for drinking water purposes represent both *demand-side provision* CPR problems that invoke a conflict of interest. Farmers' and resource users' missing motivation to keep the surface water in a good condition would be labeled a *supply-side provision* CPR problem.
The environmental problem of pesticide use is thus a threefold CPR problem: the one of over-appropriation of the resource surface water through its pollution with pesticides; the one of demand by resource users to either use or pollute surface water; and the one of lacking resource maintenance, i.e. an insufficient supply of clean surface water. The triple CPR problem represents a resource use conflict between surface water use for drinking water and the maintenance of a stable aquatic ecosystem and surface water use as a dumping site for pesticides.

Such an environmental problem can be solved through institutions, that is rules, norms and regulations. These can incentivize users to change their current user behavior and start taking care of the resource. The IRR is the analytical tool box that enables us to assess the degree to which such institutions exist in the context of Costa Rican agriculture and whether they address the resource use conflicts and potentially contribute to the solution of the environmental problem (Gerber et al., 2009).

2.3 Pesticide Use – a Complex Environmental CPR problem in Costa Rica

In Costa Rica – for a map of Costa Rica's location in Central America, see Figure 2 – agricultural productivity is fundamental since the country faces a growing population and scarcity of agricultural land (Morera, 2000). Tropical fruits enabled developing countries in the tropics to raise their farming incomes. They *"have become a major driver of economic globalization by closely linking tropical agricultural producers to consumers in temperate locations"* (Shaver et al., 2015, 75). These non-traditional agricultural exports (NTAEs) played a crucial role in guaranteeing Costa Rica's role on the global food market. To sustain agricultural intensification and the cultivation of NTAEs, Costa Rican farmers apply pesticides that guarantee the yield of monocultures like pineapples (de La Nación, 2015). However, uncontrolled, excessive and "uneconomic or unnecessary" (Eyhorn et al., 2015, 4) pesticide use outweighs the aforementioned positive effects. Quarcoo et al. (2014, 97) give a fit summary of the controversy by stating that *"pesticides are economic poisons and must be treated as compounds that perform a great service when used properly, improper use on the other hand sometimes leads to losses that far outweigh their benefits"*.

The environmental problems that arise from pesticide exposure are a frequently studied topic in Costa Rica (Daly et al., 2007; Castillo et al., 2000; Echeverría-Saénz and Barata, 2012). Biodiversity in Costa Rica makes up five percent of the global biodiversity and is home to "500 000 species of plants, animals and microorganisms" (Gámez, 2012, 77). Costa Rica's "native biodiversity" is exposed to pesticides and a reduction of pesticides would decrease the threat to many species (Schaal, 2012).

For this study, we focus on water contamination through pesticides, which in Costa Rica is particularly heavy in the regions close to the banana and pineapple plantations on the Carribean side of the country (for a map of Costa Rica, see Figure 1). Some villages in the canton of Siquirres, in the province of Limón, have no access to drinking water due to the pesticide contamination of the water (spring and surface water) caused by the region's pineapple cultivation. Drinking water for those communities is provided via trucks and costs about 27.000 US-dollars a month – a cost that is covered by the State, not by the contaminator[1].
A case in the canton of San Carlos, in the province of Alajuela, has come to public attention when more than 5.000 inhabitants drank water contaminated by the herbicide Bromacil for various days. This incident lead to the closure of the aqueduct; the communities were supplied with water from other suppliers[2].
The contamination of drinking water has led some of the communities to complain the pineapple industry's action to the Inter-American Commission on Human Rights[3]. Even though sentences by the Constitutional Chamber of the Supreme Court oblige the Costa Rican state to take actions that counteract the contamination, little progress has been made. Decisions number 2009-9040 and 2009-9041 from the Supreme Court rule that the Ministry of the Environment (MINAE) and the Ministry of Health (MS) as well as the national water supply operator (AyA) are responsible to develop an action plan and implement measures that tackle the pesticide contamination in the respective areas. The court authorized the MS to prohibit certain active ingredients and to close plantations that had not complied with the law. However, little progress in favour of the communities has been made and twelve years after having detected the contamination, pesticides continue to be found in elevated concentrations in the region's water bodies[4][5].

This study focuses on the institutions that regulate pesticide use in Costa Rica and their effects on water bodies. Policies are not related to a determinate region in Costa Rica but cover the country's entire territory. However, some producers have elaborated guidelines for certain crops such as pineapples, that are cultivated in specific regions. For the analysis of the institutions, we look at the national legislation. Besides, the IRR is tradition-

[1] GRAIN, May 2015, Comunidades fumigadas en Costa Rica acusan al Estado y transnacionales ante la Comisión Interamericana de Derechos Humanos (last access April 1, 2019)
[2] La Nacíon, February 2017, Pobladores afectados por contaminación de piñera estrenan acueducto (last access April 1, 2019)
[3] Nicolás Boeglin, April 2015, La piña de Costa Rica ante la Comisión Interamericana de Derechos Humanos (last access April 1, 2019)
[4] Seminario Universidad, January 2018, Asada de zona Norte denuncia contaminación con bromacil (last access April 1, 2019)
[5] Costa Rica Hoy, June 2018 (last access April 1, 2019)

Figure 1: Map of Costa Rica

Figure 2: Map of Central America

ally applied to national rather than regional or local legislation (Reynard and Mauch, 2003; Rodewald et al., 2003). The next chapter introduces the analytical approaches.

3 The two analytical approaches

3.1 The SESF

A further development of the IAD framework (McGinnis and Ostrom, 2014), the SESF equally emphasizes the ecological and the social elements of a social-ecological system (SES). On the one side, it consists of the *resource system* (RS) and the *resource units* (RU) that belong to the RS. On the other side, the SESF defines the *governance system* (GS) that comprises the institutions that govern the use of a given resource and provide the norms and values *actors* (A) behave upon. The actors are the ones using the resource units for different kind of purposes. They come together and interact with each other in the so-called *focal action situation* (AS), the framework's core. It is in the action situation that actors interact with one another to address, discuss or regulate the resource's use and develop new institutions, like user rules, which feed back to the four elements GS, A, RS and RU, thereby altering these elements' conditions (Basurto and Ostrom, 2013; McGinnis and Ostrom, 2014; Ostrom, 2009).

By applying the SESF one can frame the ecological and social aspects of a CPR problem in analytical categories (Herzog, 2018, 48). The four main elements may furthermore appear in multiple instances. Each element

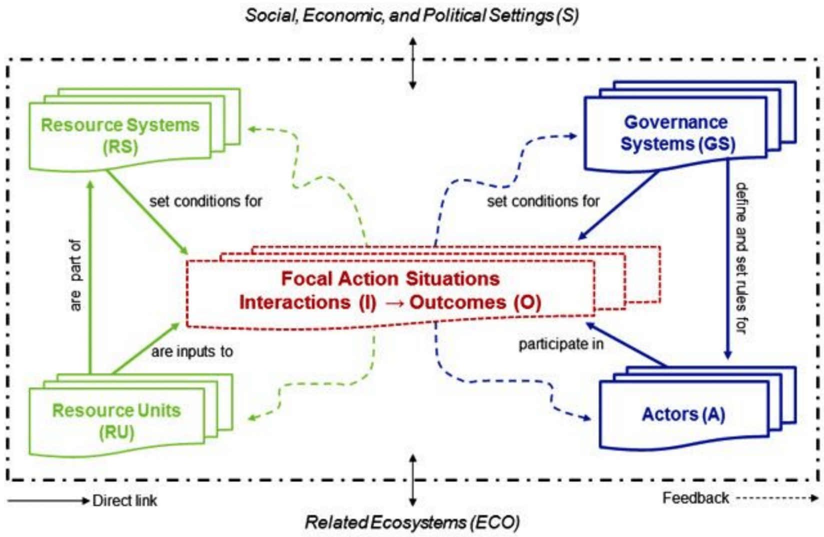

Figure 3: The SESF (McGinnis and Ostrom, 2014, 30)

comes with a list of characteristics, so-called *second-tier* variables, that describe the element more thoroughly (McGinnis and Ostrom, 2014).

The two elements *resource system* (RS) and *governance system* (GS) set the context of the SES at stake. The RS represents the ecological system the analyst focuses on. The RS thus sets the natural boundaries the actors act in. The *resource units* (RU) specify the environmental and CPR problem at stake. They are the objects of interest actors bargain about in the action situation (Cox, 2014; McGinnis and Ostrom, 2014).

The GS reflects the political system with its institutions and procedures: the policy area in which the CPR problem is tackled; the type of regime this policy area is embedded in; the institutions, i.e. the legal rules and norms, that organize the functioning of the political system on the system level and those that aim at regulating policy problems in specific sectors; and the organizations that work out these institutions (Herzog 2018, 49; Knill and Tosun 2012, 4, 41; McGinnis and Ostrom 2014). These aspects of the GS guide and structure the way actors interact with each other in the action situation. The *actors* (A) comprise all those individuals or collective actors that use, manage or pollute the resource at stake.

The *focal action situation* describes the locus where these actors get in touch, interact and produce outcomes. The SESF distinguishes an action situation's outcome as either a social performance measure, an ecological performance measure or an externality to other social-ecological systems (McGinnis and Ostrom, 2014). The outcomes affect the SES' elements and can thus alter the social-ecological system at stake. For instance, a new rule that inhibits the fishing of fish in an SES' lake adds to the catalogue of environmental policies, forces fishers to change their habit and enables the fish population to recover and prosper. By this, the new rule influences the resource system's dynamics and the resource units' – fish – conditions, alters actors' behavior and amplifies the governance system's set of rules.

The SESF is an analytical tool that reveals the elements of a SES, assesses the relations and dependencies between them, thereby highlighting the characteristics of an environmental problem. The framework illustrates the processes actors undergo to work out solutions to this environmental problem. Moreover, the framework also emphasizes the effects these solutions, i.e. the outcomes, have on the social-ecological system as a whole. By this, the SESF does not only picture a snapshot of the different resource uses within a social-ecological system but also captures the evolution and subsequent influences of institutions on resource uses and the SES under study over time. Figure 3 is the schematic illustration of the SESF.

3.2 The IRR

The IRR is a tool to analyze resource management and to assess whether the resource management promotes a sustainable use of the respective resource. Natural resources and their reproductive capacities suffer from "the industrial, domestic and urban metabolisms" (Knoepfel and Nahrath, 2006, 1) generated by globalization and other trends of our contemporary life-style. Describing the circumstances under which a resource management regime can develop and understanding the influence institutions have on resource management can teach us about the basis for environmental sustainability.

3.2.1 The IRR's analytical scope

The developers of the IRR distance themselves from Ostrom's investigations on common-pool resources and their sustainable use through self-organizing regimes. The main difference is the IRR's focus on heterogeneous rather than homogeneous resource uses. While scholars of CPR theory investigate the institutional setting that regulates the extraction of *the same good* from a resource (e.g. the use of meadows for grazing cattle or using a pond for fishing), proponents of the IRR focus on the extraction of *different goods and services* from a resource and the potential conflicts between their users.

To give an example: a water stream might be used to feed a hydro-power plant, to irrigate neighboring fields, and to provide a living environment to aquatic ecosystems. The study of the institutional setting that manages these different uses can provide insights on how user conflicts are regulated, at which levels and spots regulatory gaps exist and which configurations of institutions enhance regulatory coherence.

To grasp the complexity of resource management, the IRR analyzes all rules existent in a resource management regime: *"the property, disposal and use rights of actors who use these resources along with the policies that govern them"* (Knoepfel and Nahrath, 2006, 1). De Buren (2015, 9) explains the understanding of the interdependence between the two rule types property and use rights as *"crucial to understand (...) how ownership constitutes an obstacle for environmental policies, on one hand, and how ownership rights are limited by public constraints, on the other"*. The constitutive elements of the IRR are thus the property and use rights and the public policies regulating the use and protection of resources.

Property rights (PRs) are the legal rules and guidelines that assign rights of ownership to collective actors or individuals – namely *ownership*, *disposal* and *use* right – like for instance the possession of a piece of land or the concession of riparian rights (Gerber et al., 2009). Public policies (PPs) represent the measures that are ought to regulate and solve an environmental problem. To better understand PPs, the IRR proposes to look at *policy design* elements like the policy objective, the target group, policy instruments and the coordination among organizations responsible for the implementation of the PPs. For an overview of PRs and PPs, their elements and a comprehensive list of examples, see Table 1 in the Appendix.

Before applying this analytical framework to a particular management situation, researchers have to gather in-depth knowledge about the environmental problem under investigation – in our case water contamination due to agricultural pesticides. This includes a broad understanding of the resource's characteristics: the goods and services it provides, the respective users and the interactions leading to user conflicts. This analytical part is visualized in the bottom part of Figure 4. It is here that we apply the SESF to outline the different resource uses, the diverse users and the user conflicts. Once we have delineated the resource use situation – also called *de facto* analysis – we apply the IRR to understand its regulation – also referred to as *de jure* analysis.

3.2.2 The IRR's elements

The IRR's main contribution compared to other analytical frameworks that evaluate the regulation of resource protection and use is its consideration of property rights *and* public policy in one analytical frame (the two different IRR elements with their respective sub-elements are elaborated in Table 2 in the Appendix).

The IRR is not only a means to describe the complexity of a resource management regime[6]. It also provides two "dimensions" along which one can classify the resource management regime under study: extent and coherence (De Buren, 2015). This classification allows to evaluate the capacity of a resource regime's public policies (PP) and property rights (PR) to combine the resource's different uses and its protection in a sustainable way. The hypothesis underlying these two dimensions is that a high level of both, extent and coherence, is a necessary prerequisite for a sustainable resource use (Gerber et al., 2009).

Extent Extent refers to the *number* of services and goods in use (provided by a resource) that the resource management regime under study regulates at a given time (Gerber et al., 2008, 798). As Dupuis and Knoepfel (2016,

[6] "A natural resource regime is an explicit (or implicit) structure of rights and duties characterizing the relationship of individuals to one another with respect to that particular resource" (Bromley, 1992, 8)

10) put it: *"(...) a regime for the protection of sites with a maximum extent would regulate all of the uses that cause environmental damage"*. The extent of a resource regime thus reflects how many of the different resource uses the regime covers. By this, a regime's extent partially reflects the regime's degree of sustainability: a regime that regulates one out of ten resource uses is surely less effective in managing the resource's different uses and the user conflicts among them than a regime that deals with nine out of ten resource uses.

Coherence The dimension coherence measures *"(...) the degree of coordination of the various user-actors within the regime"* (Gerber et al., 2008, 798). Coherence is furthermore a qualitative means to evaluate how *"the measures provided by the legislator can contribute to the fulfillment of the defined objectives"* (Dupuis and Knoepfel, 2016, 11). It thus asks about the regulations' capacity to aim at their predefined goal. A lack of coherence may explain policy and implementation failure. Gerber et al. (2009) distinguish *internal* and *external* (in)coherence when they investigate coherence within the property-rights system or within public policies and across these two types of rules respectively.

The different regime types Based on the two dimensions *coherence* and *extent* one can classify the resource regime at stake. A resource regime is **non-existent** if coherence and extent are low, mostly due to the fact that no regulation of the resource exists. A regulation may be missing because policy makers do not pay a resource's scarcity the needed attention. A **simple** regime has a low extent but a high coherence, indicating that even though the quantity of legal texts concerning the resource uses is limited they are qualitatively well designed. The **complex** regime is characterized by a high quantity of legal rules that coordinate the uses of the given resource, but which are too incoherent in the way they define a fit rationale be-

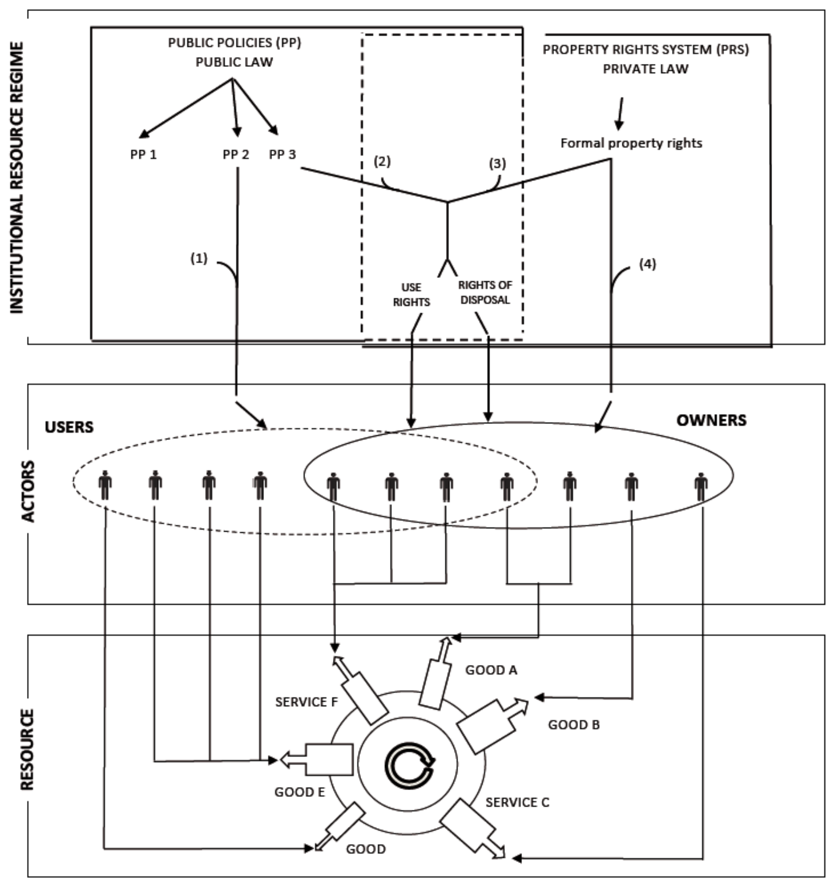

Figure 4: The IRR (Nahrath and Brethaut, 2016)

		Extent	
		low	high
Coherence	low	in-existent regime	complex regime
	high	simple regime	integrated regime

Table 1: The four regime types (Gerber et al., 2009)

tween policy objectives and the measures to reach those. The regime type that provides a sustainable resource management is the **integrated** regime. Within this category, all goods and services that the use of a resource provide are regulated. Moreover, public policies and the property-rights system effectively mesh. This regime type has rarely been detected in studies of resource regimes' effectiveness in the 21st century (Knoepfel and Nahrath, 2005). Gerber et al. (2009) claim that this type is mostly observable in cases where the resource is in public ownership, such as forests. For an overview of the different regime types, see Table 1.

To date, the IRR has mostly been applied to resource management questions in the Swiss context, for instance air (Ammann, 2000), water (Reynard and Mauch, 2003), soil (Gerber et al., 2013), and landscape (Leimbacher and Perler, 2000); and to the management of activities that potentially harm the environment, like touristic activities in the Swiss Alps (Nahrath and Brethaut, 2016) or contaminated sites management (Dupuis and Knoepfel, 2016).

This paper contributes to the IRR literature in a threefold way: first, it is the first to use the IRR framework to investigate pesticide management related to water quality; second, the study applies the IRR framework to a case study in the Global South and provides a critical appraisal of the IRR in this context; third, the paper complements the analysis of institutions in a CPR problem situation of water pollution through the IRR by doing the de-facto analysis of the resource use situation with an application of the SESF.

4 Analysis – applying the SESF and the IRR to study a resource management regime

Data Gathering and Analysis

Based on De Buren (2015), we take a bottom–up approach. We start with the assessment of the resource use situation to identify potential user conflicts – the de facto analysis – to then investigate the institutional setting that ought to regulate these user conflicts – the de facto analysis.

For the first part of the analysis, we use literature from peer-reviewed studies. Data is gathered around various topics, such as pesticide exposure, the conflict between development and protection, the uses and users of the various resources and information about the actors in agriculture. We also use international platforms, such as databases from the United Nations Food and Agricultural Organization to corroborate the analysis with recent and solid data.
The second part of the study presents the results of the analysis of the current institutional regime regarding water use in Costa Rica. The main data of reference is the Civil Code, the Constitution and legal documents that cover water use and water protection in Costa Rica, like laws, regulations and management plans. The sources of these documents are the websites of the responsible ministries and the state (e.g. Sistema Costaricense de Informacíon Jurídica) [7]. Another data source is the policy database of the UN Food and Agricultural Organisation[8].

To complement the analysis, the paper's first author conducted five interviews (for a list of interviews, see Appendix, Table 4). According to de Buren (2015, 15) interviews are an important aspect of the IRR analysis because *"these secondary data provide a basis for verifying the relevance of the primary data and balancing the importance of the institutional drivers"*. The interviews were

[7] Sistema Costaricense de de Informatíon Jurídca (last access Apil 1, 2019)
[8] FAOLEX Database (last access April 1, 2019)

conducted in Costa Rica in May 2015. The interviewees are experts and senior representatives of country-specific public agencies. The interviews served to obtain background information about the existing institutional setting, to reconstruct political decision-making and to assess developments and changes in the institutional setting.

4.1 Analyzing the resource use situation with the SESF – the *de facto* analysis

Within the social-ecological system (SES) of Costa Rican surface water use we find the CPR problem we investigate and the institutions that ought to manage this problem. The analysis of the given SES thus gives answers to the questions of a) in which resource system we find the CPR problem and which shape it takes; b) who is creating and who is solving the CPR problem; c) who suffers from the CPR problem; and d) what the policy structures are like in which solutions to the problem are developed. Figure 5 represents the application of the SES Framework to our case study.

We describe the SES's elements with the so-called *second-tier characteristics* as outlined by McGinnis and Ostrom (2014) and indicate their number in brackets[9].

The **resource system** (RS) is the whole of Costa Rican bodies of surface water. The country has three drainage basins which themselves are distinguished in 34 watersheds. The RS's *sector* (RS1) is thus water; the *clarity of system boundaries* (RS2) is given, since the countries' water basins can clearly be defined in hydrological terms. The total amount of surface water produced internally is 113 10^9 m^3/year, representing the *size of the resource system* (RS3)[10].

Regarding *human-constructed facilities* (RS4) one has to note that water sources in Costa Rica are heavily used for hydroelectric energy generation (Bower 2014, 87; Bonell and Bruijnzeel 2005). Although not directly related to the use of surface water as drinking water or as a sink for polluting substances, the country's twelve dams are a common human-constructed facility that alters the water bodies' structures[11].

The *productivity of the system* (RS5) and the *predictability of system dynamics* (RS7) are two complementary characteristics. The first could be interpreted as the aquatic system's capacity to produce or regenerate its stock. Regarding the study's environmental problem of water pollution through pesticides, one can also rely on Fleischmann et al.'s (2014, 447) statement that *"(...) for pollutants, productivity can be interpreted as the rate at which pollutants are released into the environment"*. We adapt this aspect, claiming that in our case the system's productivity reflects the surface water's regeneration rate and related to this the amount of pesticide residues that remain in the surface water. The second characteristic can be defined as the distribution of those residuals in the water bodies. It reflects thus the concentration and distribution of the pesticide residues in surface water. The *equilibrium properties* (RS6) of the resource system are also subsumed under this interpretation, reflecting the water bodies' dynamic of absorbing and integrating polluting substances.

We do not consider the RS's *storage characteristics* (RS8) since we look at streams. The resource system's *location* (RS9) is, again, the entire Costa Rican territory.

The **resource units** (RU) are the different types of use of the resource surface water: a) the use of surface water as a sink in which pesticides release through runoffs after they have been applied to fields; b) the use of surface water for drinking water; and c) the use of surface water by the environment, that is, the natural aspect of water providing for life in aquatic ecosystems. The *number of units* (RU5) is thus three.

Resource unit mobility (RU1) is rather difficult to estimate for our case study since we define the RU as the *use* of a resource. Considering the resource, i.e. surface water, its mobility can be described as fluctuating: in times of drought, surface water in streams flows slower than in times of intense precipitation.

The resource units' *growth or replacement rate* (RU2) takes up what has already been discussed under the element RS: the resource's capacity to regenerate its stock. For our case study this represents the surface water's capacity to a) take in pesticide residues and their persistence in the respective water body; b) be available for drinking-water use; and c) be available for the aquatic ecosystem.

The *interaction among resource units* (RU3) reflects the emergence of the CPR problem that is based in the different uses: the exchange of surface water between the different types of surface water use. Pesticide residues enter the water bodies and pollute the surface water that is also needed for drinking water purposes and by the aquatic ecosystem to live and prosper.

This characteristic is closely linked to the *spatial and tem-*

[9]We keep the freedom of freely interpreting the second-tier characteristics as we see they fit the case study. This implies that we might not consider all second-tier characteristics available for our analysis

[10]cf. FAO Aquastat, years of reference are 2013–2017 (last access June 15, 2019)

[11]FAO Aquastat (last access June 19, 2019)

application.png

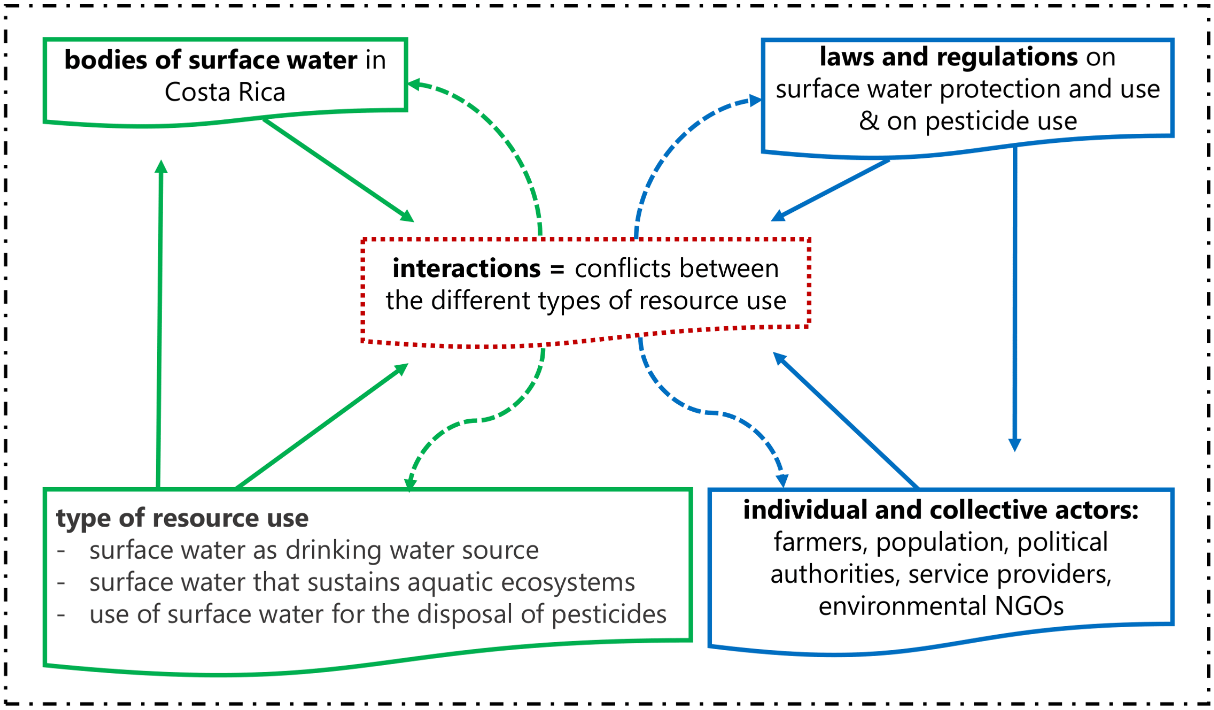

Figure 5: The application of the SESF to the case study; own depiction

poral distribution (RU7) of the resource unit, a characteristic that is inherent to surface water. For water runs in one direction only, making it an asymmetric CPR. Something happening to water upstream, like its pollution with pesticide residues, inevitably has an effect on the water users downstream, like drinking-water users or the aquatic flora and fauna (cf. Herzog, 2018, 60).
The *economic value* (RU4) of the use of surface water in 2016 was a) 0.002 US Dollars per m^3 for agricultural use; b) 0.003 US Dollars per m water for human consumption; and c) 0.0002 US Dollar per m^3 for aquaculture (Vargas and Lee 2017, 13). The value of water for the aquatic ecosystem is evidently less than the water's value for human purposes, its consumption and its application in agriculture.
We consider the characteristic *distinctive characteristics* (RU6) to highlight the three resource units' differences: the use of surface water for different purposes by different actor groups and ecological components.

The **governance system** (GS) of our case of pesticide use and surface water pollution in Costa Rica consists of the following *second-tier characteristics*[12]. The social-ecological system's *policy area* (GS1) is not one single one, but several ones, since the topic of surface water use and protection is covered by different domains: water policy, environmental protection policy, mining and agricultural policy.
The *geographic scale of the governance system* (GS2) corresponds to the Costa Rican territory (see also Figure 1) which comprises an area of 51.100 km. The *population* (GS3) of Costa Rica amounts to roughly 5 million people. Costa Rica has a long-lasting democratic history, with its democratic institutions developing already in the outgoing nineteenth century, and is considered *"(...) Latin America's longest-standing and most stable democratic regime"* (Booth and Seligson, 1989, 113). Its *regime type* (GS4) is the one of a presidential government[13].
The country's main *rule-making organization* (GS5) is the Asamblea Legislativa de la República de Costa Rica [14].
The *rules-in-use* (GS6) are the laws and regulations on pesticide use, on the use of surface water and on surface water protection the Costa Rican government and its

[12] We are referring to the "alternative list" of second-tier properties for governance systems by McGinnis and Ostrom (2014)
[13] German Ambassy, San José; FAO Aquastat (last access June 15, 2019)
[14] Asamblea Legislativa República de Costa Rica (last access June 15, 2019)

responsible authorities have developed. These comprise the Water Law (1942, N 276), the Environmental Law (N 7754, 1995), the General Law on Drinking Water (N 1634, 1953), the Law on Biodiversity (N 7788, 1998), and the Mining Code (Law N 6767, 1982). Besides these legal texts, the Costa Rican constitution (CP) (1949) and the Costa Rican Civil Code (CC) (Law N 63, 1887) are relevant for they define property right titles and public goods (CC) and consign to the Costa Rican state the responsibility to protect and use the country's natural resources (CP). The *property-rights system* (GS7) is part of the IRR analysis and will be discussed in detail in Chapter 4.2.2.

The governance system's *repertoire of norms and strategies* (GS8) are made available for the actors to use. In our case study, these refer to the public administration, drinking water operators and to a limited extent to polluters that we outline in more detail when describing the actors at stake. The *network structure* (GS9) *"refers to the connections among the rule-making organizations and the population subject to these rules"* (McGinnis and Ostrom, 2014). As will be seen in the IRR analysis, the rules regarding pesticide use and surface water protection rarely address specific actor groups (see Chapter 4.2.2). The governance system's network structure is thus not strongly evolved.

The *historical continuity* (GS10) of the Costa Rican governance system is characterized by political stability and the ability to develop socially and economically (Cruz, 2000, 278, 284). Moreover, *"(...) Costa Rica enjoys one of the oldest democratic regimes in the hemisphere, politically independent courts, and a rights-friendly constitution (...)* (Wilson, 2009, 9).

The **actors** in the social-ecological system that comprises pesticide application in agriculture, drinking water use from surface water and use of surface water for aquatic ecosystems in Costa Rica are manifold. They are farmers of mainly fruit plantations who apply pesticides; they comprise the population that uses the rivers' surface water as drinking water; they also encompass the political authorities responsible for the development and the implementation of pesticide use regulations and water protection laws; the Costa Rican Institute of Aqueducts and Sewers (AyA), which is the main drinking water operator and the target group of several legal documents to be responsible for maintaining drinking water quality standards; and the regional drinking water service providers. Regional environmental NGOs that raise awareness for the pollution of the countries' surface water bodies fall under this element as well – they are, however, not investigated more specifically in this paper as we focus on the national arena. The *number* (A1) of actors is thus not specifically countable nor is actors' *location* (A4) definable.

Actors' *socioeconomic attributes* (A2) differ depending which actor one focuses on: small-scale farmers are more likely to have less financial resources than large-scale farmers while collective actors at the state level possess influential power that environmental NGOs strive for.

Regarding the *history or past experiences* (A3) with agricultural practices and thus the use of pesticides, Costa Rica has a long history of smallholding farming, which changed when new export crops were introduced and the country started selling its agricultural products to the international market (Booth and Seligson, 1989, 113). Moreover, initiated by the IMF (International Monetary Fund) and US-American foreign aid incentives, highly industrialised banana production systems were installed (Hall and Ko, 2005, 55). In 2016, around 11% of the country was cultivated, the area on which crops were permanently cultivated amounting to 312.000 ha[15].

Costa Ricans' experience (A3) with drinking water provision in rural areas is rooted in the Comités de Acueductos y Alcantarillados Rurales (CAAR) and the Asociaciones Administradores de Sistemas de Acueductos y Alcantarillados Sanitarios (ASADAS), the latter of which has an agreement with the Costa Rican Institute of Water and Sewerage (ICAA) from which the ASADAS obtain their rights for the withdrawal and management of water (Madrigal and Schlüter, 2011, 1664). The roughly 1500 ASADAS provide drinking water and sanitation services to 29% of the population in rural and periurban areas (Vargas and López Lee, 2017, 13). While it is mostly state water utilities, like the state service provider AyA that serves 47% of the population, that provide drinking water in urban areas (Madrigal and Schlüter cf. 2011, 1663; Vargas and López Lee 2017, 13). Access to drinking water in Costa Rica is with more than 95% one of the highest in Latin America (Madrigal and Schlüter, 2011, 1663). However, it is considerably lower in rural areas[16].

As the study by Madrigal and Schlüter (2011, 1670) of Costa Rican community-based drinking water organizations (CBDWO) showed, in the case of well performing CBDWO their *leadership* (A5) was strong with a stable engagement of water board members and a strong position of the organization's presidency. When the organizations' performance was low, one could observe a lack of

[15] FAO Aquastat (last access June 15, 2019)

[16] 92% of the rural population had access to safe drinking water in 2015, while the share was 99.6% for the urban population. In total, 97.8% of the Costa Rican population had access to safe drinking-water in 2015, cf. FAO Aquastat (last access June 19, 2019)

expertise among the water board members.

Regarding *norms/social capital* (A6), it can roughly be said that Costa Ricans are supportive of community work and personal engagement in political activities; however they are less inclined to protest (Booth and Seligson, 1989, 115). In general, the Costa Rican civil society is rather frail (Wilson, 2009, 66f.), but citizens are sensitized for the need to protect the country's water resources (Bower, 2014). Moreover, communities actively shape and sustain their community-based drinking water organizations (CBDWO) through active participation in the organizations' administration, design and finance which improves the organization's overall performance (cf. Madrigal and Schlüter, 2011, 1663, 1671).

The characteristic *knowledge of SES/mental models* (A7) cannot be specified for our case since our study did not comprise an evaluation of actors' mind sets regarding the social-ecological system at stake.

The *importance of the resource* (A8) surface water can be stated as high for its use as drinking water and as a prerequisite for stable and healthy aquatic ecosystems. Surface water is important for agriculture as a source of irrigation, and, as a side-effect of pesticide application as a sink for polluting substances.

We do not consider the last characteristic *technologies available* (A9) since our study does not focus on the different technologies available but on the laws and measures developed and applied that ought to manage the different surface water uses.

We define the case study's **action situation** as the resource use conflict between surface water pollution by pesticides and surface water use for drinking-water and aquatic ecosystems.

Harvesting (I1) can be described as the use of surface water a) as a sink for pesticide residues; b) for drinking-water purposes; and c) for the prosperity of the countries' aquatic ecosystems.

Information sharing (I2) among actors can be varied: information on the regulations for water protection and the application of pesticides can be communicated; data on the concentration of pesticide residues in surface water can be distributed; and general information on who is using surface water at what site for one of the three specific purposes[17].

Deliberation processes (I3) would be all those instances in which a moderating third party advised those actors causing the environmental problem of water pollution and those suffering from the pollution on how to proceed to solve the issue.

Conflicts (I4) clearly describe the very nature of the action situation: the user conflict due to different use types and needs of surface water.

Banana is Costa Rica's number one export good, making up 16% of the country's export products, followed by tropical fruits (14%)[18]. Banana production in Costa Rica is said to consume half of the country's pesticide imports (Barraza and Wesseling, 2011)[19]. Studies proved that pesticide residues enter water streams through runoff from cultivated fields, leading to a deterioration of the aquatic ecosystems and disturbing their natural dynamics which manifest themselves in death of fish, intoxication of aquatic invertebrates, the death of algae grazers and an increase of algae bloom, all of which leads to more decaying organic material in the water system that as a consequence shows lower levels of dissolved oxygen concentrations (Diepens and Castillo, 2014, 81). Pesticides' negative influence on aquatic ecosystems is severe and widespread in Costa Rica and Central America in general (Castillo and Ruepert, 1997; Devine and Furlong, 2007; Echeverría-Saénz and Barata, 2012; Henriques, 1997).

The application of pesticides on agricultural fields is not only harmful for the aquatic environment, but also for human health as several studies from Costa Rica and Central America in general show (Bravo and Wesseling, 2011; Fieten and van Wendel de Joode, 2009; Wesseling and van Wendel de Joode, 2001). Studies suggest that an exposure to specific pesticides by soon-to-be parents in Costa Rica may increase the likelihood of leukemia in children (Monge and Partanen, 2007) and that heavy pesticide use may be associated with an increase of cancer incidences in rural regions (Wesseling and Ahlbom, 1999). Moreover, a study by Humbert et al. (2007) showed that in Costa Rica five substances – one of it being ethoprophos – contribute to more than 75% of the aquatic ecotoxicity and that for humans it is two substances that make out 90% of human toxicity caused by pesticides.

These health issues related to pesticide exposure are aggravated when pesticide residues are found in drinking water, as was the case in the canton San Carlos in the province of Alajuela where local residents consumed drinking water that was contaminated with the herbicide bromazil, which is applied to pineapple plantations[20].

[17] The use of surface water as a sink for pesticides can be distinguished in point and diffuse sources of contamination

[18] the Observatory of Economic Complexity (OEC), Costa Rica (last access June 20, 2019)

[19] Two pesticides commonly used on banana and pineapple plantations in Costa Rica are chlorpyrifos and ethoprophos (Diepens and Castillo, 2014, 74)

[20] Diario Extra, April 18, 2016 (last access June 20, 2019)

We consider *lobbying activities* (I6) as any action of an actor group that confronts the user conflict, be it in a positive way by trying to attenuate it, be it by supporting the status quo of the situation. *Investment activities* (I5) may fall under the category of lobbying activities when actors put financial resources into an action that either intensifies or diminishes the user conflict.

Since for this study we have not looked at actors' common actions and their connections among each other, the characteristics *self-organizing activities* (I7) and *networking activities* (I8) are not considered. However, in a more detailed study of actors' networks, as has been done by Gruber (2017), these characteristics should be acknowledged. *Monitoring activities* (I9) and *evaluative activities* (I10) are interpreted as all those actions by actors that report on surface water quality.

The *social performance* (O1) and the *ecological performance measures* (O2) as well as the potential *externalities to other SESs* (O3) that result from the action situation's interactions may become visible through a study of the institutions' *outcomes*. The institutions ought to tackle the user conflict and thus might induce a change within the action situation – the resolution of the user conflict and the environmental problem – which can then lead to alterations of the resource system, the resource units and the actors' situation which represent such social and ecological performances.

4.2 Analyzing the institutions with the IRR approach – the *de jure* analysis

We investigated the regulation of two services of the resource surface water in Costa Rica affected by pesticide application: water for human consumption and water for the aquatic ecosystem. In the following, we discuss the results of the analysis of the Costa Rican Institutional Resource Regime regarding water, based on the IRR framework (an inventory of all texts can be found in Appendix, Table 6).

4.2.1 Extent

The extent of the Costa Rican IRR for water is satisfactory. The analysis showed that rules for the use and the protection of water regarding the two services *drinking water* and *supporting the aquatic system* exist. Three of the experts who had been interviewed (interview 1, 3 and 4, for more information see Appendix, Table 4) confirmed that the extent of the IRR regarding water is satisfactory. However, interviewee 1 stressed the general lack of a regulation that would govern the protection of surface water quality. The same expert also explained this lack: the regulation on the evaluation and classification of superficial water quality (N 33903, 2007) does not protect superficial water bodies to the full extent, because parameters regarding pesticides are not up to date. The extent being

4.2.2 Coherence

Internal Coherence: Property–rights system

Water ownership is a complex issue in Costa Rica, that is regulated through various legal texts and by several political entities. The Costa Rican Civil Code (CC) (Law N 63, 1887) and the Constitution (CP) (1949) make little or no reference to property rights regarding water. The CC defines general property titles (Art. 264). It defines public goods as anything that is of public utility and all remaining things as private (Art. 261). According to Art. 276 of the CC, the provision of water is governed by common law, as long as they do not conflict with special laws.

Common law in Costa Rica is responsible and entitled to regulate the property and user rights of all water bodies. The only article within the CC making a reference to public and private waters is Article 489. This article states that fishing and hunting are allowed in public waters, in accordance with respective regulations. The article further limits hunting on private property to the permission of the property's owner.

The Costa Rican constitution (CP) establishes state sovereignty over all territorial waters and the state's exclusive right to use and protect natural resources and natural wealth, among them water (Art. 6). The state has furthermore the power to guarantee welfare to all residents within its territory, in which all persons are entitled to a healthy and ecologically balanced environment (Art. 50). Everybody is entitled to claim this right and to report acts that violate a healthy and ecologically balanced environment.

The CP furthermore declares territorial waters State property and places the responsibility for the provision of a healthy environment to the Costa Rican population on the State. The Civil Code provides no diversification of property titles, use or disposal rights on water whatsoever and explicitly refers to the law as means to fill this regulatory gap.

The main law of reference concerning water is the Water Law (1942, N 276). Water lies within the public and private domain, which is the Water Law's overreaching principle. It lists *public* water bodies, like lagoons (Art. 1, II), (III), rivers and their direct and indirect tributaries, streams or springs (IV), constant or intermittent currents (V), all currents that directly or indirectly flow into the currents mentioned in Art. 1, V (VI) and groundwater which is not provided by wells (IX). The property and dominion over those waters can be transferred via concessions granted by the State (Article 2).

The following waters are of *private* property: rainwater[21], ponds formed on the grounds of private property[22], and groundwater that the owner obtains from own ground (III). Other articles regulate that general uses of water – drinking, swimming, fishing, washing clothes – are open-access uses; while special uses dedicated to public or private entities need an authorization issued by the MINAE (Article 17).

According to Arias and Alvarado (2013, 61) the Costa Rican Water Law is out-dated and *"insufficient to meet the needs of the national water sector due to increased demand, poor management, increasing environmental and social conflicts and problems in terms of quantity and quality"*. The interviewed experts confirmed this claim and interviewee 4 (from the Tribunal Ambiental Administrativo) underlined that the Water Law "was made for another Costa Rica" and that the distinction between private and public water bodies is actually obsolete. Today, water "is nobody's and everybody's".

The analysis further revealed that the document regulating property rights of water bodies (the Water Law) is overlapping with various other legal documents like the Mining Code (Law N 6767, 1982), the Environmental Law (N 7754, 1995), and the General Law on Drinking Water (N 1634, 1953) and that the notion of water as a public good has overruled the differentiation between private and public water bodies. The Law on Biodiversity (N 7788, 1998) is also worth mentioning since it establishes that environmental damage has to be avoided and that the State has to take the necessary measures to "restore, retrieve and rehabilitate (. . .)" (Art. 54). As soon as such an environmental damage is done to water resources, this law plays a role for the water resource regime.

The Mining Code specifies that those entitled to exploit the environment have to comply with all rules, the legal and regulatory requisites concerning environmental contamination and restoration of the renewable natural resources (Mining Code, Art. 97). This code further stresses that any behaviour that deteriorates the natural environment and its goods, especially the resources water, air and soil, is prohibited (Mining Code, Art. 99).

The Environmental Law (N 7754, 1995) establishes the criteria that should guide the protection and the sustainable use of water: *"a) Protect, conserve and, where possible, recovering aquatic ecosystems (. . .) [and] b) Protect ecosystems that regulate water regime (. . .)"* (Art. 51).

These laws and their respective articles demonstrate that the use of the environment and its natural resources is in fact limited by the above mentioned rules and that the use of water has to be orientated towards a more sustainable use. According to the Environmental Law, uses have to abstain from all action that cause damage to the environment, which is defined as *"a crime of social nature, affecting the foundations of the existence society: of economic nature because it puts the materials and essential resources for productive activities at risk; of cultural nature as it endangers the way communities live, and ethical because it threatens the very existence of present and future generations"* (Environmental Law, Art. 2, let. E).

Internal coherence of the regulatory system is only partially given, because the existing differentiation between private and public rights to water is outdated by more recent regulations that re-define property and use rights and adapt the private law provisions to the modern context of resource scarcity. While the Water Law clearly distinguishes between private and public water bodies, more recent legal documents bring the notion of only public water bodies forward. A plan for a new Water Law exists since 2002, but has been stuck in the Legislative Assembly for almost 15 years. The project (Ley del Recurso Hídrico) includes principles such as defining the access to water as a human right and water as a public good. In order to unify all existing property titles and laws concerning water and its use the project proposes an encompassing document where duties, rights, responsibilities, and sanctions are adapted to the needs of current developments.

Internal Coherence: Policy design

Having focused on the institutions and their lack of coherence, we subsequently drive the attention towards the

[21] The owner of the property can dispose of those waters under the condition that this action does not cause any harm to the public or to third parties (Art. 3, I).

[22] If the ponds are formed on grounds of communal use they belong to the respective communities (II).

policy design that surrounds the policies and puts them into effect. We assess the coherence and efficacy of the Costa Rican water policy design along the elements coordination of executing bodies, policy objectives, target groups and policy instruments.

Coordination of the executing state bodies The former section highlighted the discrepancy between the multiple policies from different policy sectors that touch on the use of water and on its protection. In Costa Rica, the protection of water from pesticide use is thus an endeavour that includes various political entities.
The Ministry of Health (MS) has to guarantee the quality of drinking water and has to work together with the Ministry of Agriculture (MAG) in matters concerning water contamination caused by vegetal health protection. The Ministry of Environment and Energy (MINAE) is the main political entity in charge of environmental protection and management in general. Some responsibilities are delegated to Directories, such as the Direction for the Management of Environmental Quality (DIGECA) or the Directory for Water (DA). The institutional arrangement even includes a juridical body, the Administrative Environmental Court (TAA). The TAA ensures that environmental damages and other trespassing of environmental law do not pass unrecognized and that disputes are solved. Lastly, the Phytosanitary Service of the State (SFE, an organ of the MAG) is in charge of pesticide registrations, restrictions and prohibitions (see Appendix, Table 8).
Those executing State bodies leave little to no space for regional or even private institutions in the decision making process. The great variety of political entities involved in the IRR on water also bears the risk of overlapping responsibilities and inefficient allocation of rights and duties. According to the interviewed experts, coordination across State entities is in place. However, the experts assessed the functioning of the cooperation differently: as either smooth (interviewee 2) or challenging (interviewee 1). Interviewee 4 stated that all political bodies mentioned above claim to be responsible in matters of water protection. Though in the event of an urgency – for instance an acute case of water pollution – when rules have to be put in practice, those responsible entities place the responsibility for the management on each other.

The analysis and the verifying interviews showed that in Costa Rica a multitude of policies and political entities exist to protect the services the resource water provides; but often responsibilities overlap and are sometimes even compromised by pressure among the executing state authorities , often put on by industrial lobbies (interview 1). Coordination across policy sectors is given, but challenging and more efforts are needed to assign clear responsibilities or to empower the MINAE as principal coordinating body regarding the regulation of surface water use and protection (interview 1).

Policy objectives In Costa Rica, state authorities consider pesticide use as a problem for the protection of the resource as this problem is explicitly mentioned in several legal documents. The National Plan for Integrated Water Management (PGIRH 2009) and the national Water Agenda (ADA 2013) identify pesticide contamination as a major political challenge. They are thus a step ahead of the other politically binding documents, putting diffuse contamination on the political agenda.
The investigated legal texts acknowledge the risks and harms pesticides bring about. The Health Law further considers as political challenge *"every action, practice and operation that deteriorates the natural environment, which could alter the composition or the intrinsic characteristics of its basic elements, especially air, water and soil, (. . .)"* (Art. 263). The Law also recognizes as contaminating *"substances of any kind that alter the physical, chemical and biological characteristics of water which make its use dangerous for human health, for terrestrial and aquatic wildlife or make it unusable for domestic, agricultural, industrial or recreational uses"* (Art. 268).
None of the interviewees contested that pesticide use is a collective problem for the protection of water bodies. However, it is not the only challenge on the political agenda. As the graph in figure 6 shows, climate change as well as floods are also relevant risks in the selected catchments. Contamination is of high priority in seven out of 34 catchments and of medium priority in most of the 27 remaining.

Target groups The analysis of the legal texts revealed that they do not provide instruments that clearly aim at reducing pesticides' effects on the two goods – drinking water and stable aquatic ecosystems – by, e.g. changing the polluters' behaviour. Neither do these texts identify a specific target group at which the instruments would be addressed. One could conclude that a lack of target group-identification goes hand in hand with missing instruments, because in order to change polluting behaviour of actors, policy makers have to identify those responsible for the contamination in the first place. European frameworks (Mauch et al., 2000) often refer to the polluter-pays principle. This principle establishes a causality between the harm to the environment and the cost of the damage arising from this harm.
In the Costa Rican case, various articles of laws and regulation hint at environmental damage and the repercus-

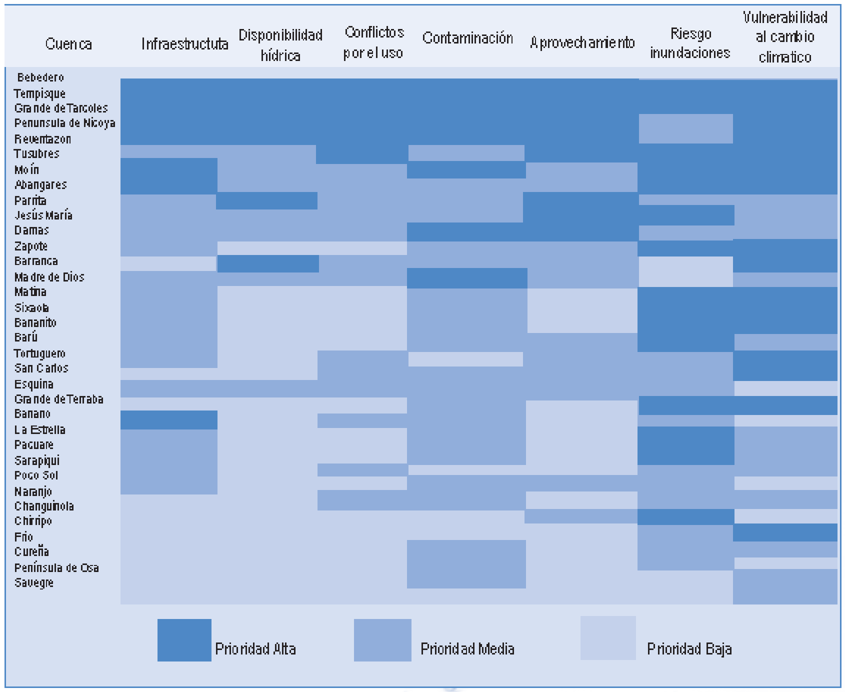

Figure 6: Problems associated with water resources and their priority of attention (Plan Nacional de Gestión Integrada de los Recursos Hídricos (PNGIRH), 2008)

sions for the culprits. Those legal texts are relevant, because they acknowledge that environmental damage shall not pass unrecognized and unpunished. The Environmental Law defines environmental damage even as a "crime" (Art. 2, let. E) and existing action plans, such as the Política Hídrica Nacional (2008) stipulate that the contaminators have to be made responsible for their actions. The polluter-pays principle is installed within the Costa Rican IRR, however, it remains a vague principle: no binding document defines a specific target group as contaminator; agricultural practices are only mentioned as culprits in non-binding management plans; environmental damage refers to the environment in general, but no legal text elaborates the kind of damages done to water quality that would qualify as environmental damage.

Within most of the studied documents public entities are the target actors. Regulations like the Regulation on Drinking Water Quality (N 38924, 2015) and the Regulation for the Evaluation and Qualification of Superficial Water Quality (N 33903, 2007) set limits and maximal values for pesticide residuals which address entities that clean water to ensure a determinate quality of drinking water. The management plans refer to agricultural practices and the intensification of agricultural practices in general as one cause of the greater problem of water contamination. Nevertheless, the identification of the polluter within the legal water resource regime in Costa Rica is unsatisfactory, since no regulation or law make a concrete reference to agricultural practices.

An expert from the DIGECA (interview 1) as well as the judge from the TAA (interview 4) confirm the difficulty to identify a specific target group. Pesticide contamination is diffuse, which means that even if a producer cultivates close to a water source this does not mean that this farmer is the only one responsible for the contamination in the area. Even if one delimits the territory in smaller catchment areas it is impossible to determine who contaminated and to what extent. Without parameters that determine how to make the responsible pay, environmental damage in Costa Rica often remains unpunished.

Policy instruments All three experts acknowledged that various instruments exist that control the contamination at a stage at which it can already be traced. The recent Regulation on Drinking Water Quality (N 38924, 2015) states the objective *"to establish the permissible maximum limits of physical, chemical and microbiological drinking water parameters, in order to ensure the safety and the health of the population"* (Art. 1).

According to interviewee 2, the Regulation's transitory article, in which this statement can be found, has been included into the original regulation, because the original document invoked limits that were of European standard, whereas the new limits are international (World Health Organization) and north American standards (Environmental Protection Agency) that are less strict[23]. This expert is interested in providing the best quality of drinking water possible and in guaranteeing a certain standard to ensure that human health is not negatively affected. According to this expert, the end-of-pipe instruments are very effective and the ministry is working on an actualization of the regulation.

According to interviewee 1, the Direction for the Management of Environmental Quality (DIGECA) pushes the protection of the environment forward and proposes various source-directed instruments, such as maps that determine the vulnerability of a territory, similar to an environmental impact assessment. Interviewee 4 underlines the need to protect the environment ex-ante and proposes more monitoring to determine the kinds of pesticides used and to evaluate their impact on water bodies. All three experts confirm that instruments are in place to control the contamination ex-post, but lament the lack of measures that prevent contamination at the source.

Measures address the problem of water pollution from pesticide use one-dimensional and at a moment when contamination has already occurred. The provided instruments are end-of-pipe, while it would be desirable to include some instruments that avoid contamination at-source (Metz and Ingold, 2014), before the toxic substances enter the water bodies. Such source-directed instruments are only referred to by the management plans. The PGIRH (2008) suggests economic incentives to make the parties responsible for agricultural contamination pay. The National Water Policy (2009, 26) makes a specific reference to the polluter-pays-principle and to the need for the State to *"ensure the internalization of environmental and social costs of contamination in a way that those costs are assumed by whom raises them"*.

In conclusion, two aspects characterize the state of instrument-choice regarding the management of water pollution through pesticides: the contamination is diffuse, making it difficult to control the contamination of water bodies at-source; and the need to establish source-directed instruments has been acknowledged by the experts and mentioned within the political plans.

Qualification of the policy design

The public policies pursuing the protection of water bodies from pesticide contamination are rather incoherent. Even though contamination is regarded as a collective problem, only a small amount of legal texts mention pesticides and their impacts. Various regulations and laws emphasize the coordination between the different State entities; but the multitude of political entities involved and the experts' evaluations have confirmed that policy-coordination in this matter is highly complex. When problems arise, responsibilities are shifted and allocation of duties are badly coordinated.

The identification of the target group and the policy instruments to limit pesticide contamination both lack coherence, because they fail to address the target groups and to provide instruments for diffuse pesticide contamination. To a limited degree, agriculture is identified as culprit for pesticide contamination. Most of the political plans identify agricultural practices as crucial for water quality, but binding instruments remain silent on this account. The instruments provided by the public policies tackle pesticide contamination when it is already in existence and do not operate before pesticides' release to the environment. Only the management plans (which have not the same binding power as decrees or laws) address the need to protect water bodies at-source.

External coherence

The analysis has shown that the target groups (e.g. drinking water–operators) of the instruments and the holders of the property rights of water resources are not the same. All experts acknowledge that water is a public good and that the notion of diffuse contamination and the polluter-pays-principle are not sufficiently regulated for the public policies to have coercive power on the owners of the resources – in this case everybody. As a result, the regime fails to provide external coherence between the public policies and the property titles.

To conclude, policy design to protect drinking water and the aquatic ecosystem from the negative effects from agricultural pesticide use in Costa Rica is limited. Two main shortcomings are: Firstly, identification of agricultural production as culprit of pesticide contamination and the need to change farmers' behavior is not provided by the legally binding policy documents. Secondly, the

[23]The transitory article has been declared unconstitutional in 2017, which is why the current limit of pesticides in drinking water is set at 0.1 g/L

policy measures to prevent pesticide contamination at–source are rare and only explicitly mentioned in management plans, which have no legally binding power but serve as guidelines for the administration of reference. However, the SESF analysis and the interviews show that pesticide contamination is a peculiar form of contamination - it being a diffuse form of contamination makes simple solutions impossible. Better understanding of where the contamination comes from and what measures are effective in changing current application behavior might help to design policies that prevent or mitigate contamination effectively.

4.3 Classification of the regime

The Costa Rican Institutional Resource Regime for water is highly complex. Its extent – that is, the number of goods and services the resource regime regulates – is high: in various documents, the IRR describes the regulation of both goods – surface water for drinking water purposes and for a stable aquatic ecosystem – and addresses the need to protect these goods from pesticide contamination. Yet, all good intentions on paper are worth nothing, if they do not mesh each other and besides are not put in practice.

For the IRR's coherence is not satisfactory. Many legal texts exist, but regulations often overlap, are outdated, identify target groups to an unsatisfactory extent or provide instruments that address the problem's symptoms instead of its causes. Even more, the regime is highly flexible: neither does it provide binding legal texts that make the users of pesticides responsible for water contamination nor does it invoke instruments that aim at users' behavior change. The lack of strict obligations makes the regime inapt to protect water to a coercive level.

However, policy coordination is an objective of the institutional framework and the interviewed experts underline its importance. Furthermore, there is a far-reaching understanding across sectors that pesticide contamination is a pressing issue. Recent regulations and political programs are under way which address the environmental problem in more detail and precision and propose new strategies to solve it.

5 Discussion & Conclusion

This study has combined the Social-Ecological System Framework (SESF) and the Institutional Resource Regime (IRR) approach to investigate the CPR problem of surface water contamination from pesticide use in a complementary way: to unravel the different layers and components of the social-ecological system in which the CPR problem and resource use conflicts evolve; and to ray the institutions that approach this problem and the policy design within which these institutions exist. The first analysis was done with the help of the SESF. This *de facto* analysis of the case showed that the resource surface water is used in a three-fold way by the agricultural sector, by the drinking water provision sector, and by the aquatic environment. The user conflicts emerging from these different user types were conceptualized as an action situation which shapes the state of the resource itself and the system it is part of and influences the state of those who use the resource.
The *de jure* analysis highlighted the variety of guidelines and laws that the State has issued to go about these user conflicts, theoretically addressing each type of resource use. It is in the rules' complementarity and in their execution that we see deficits: many state bodies have the right to implement and oversee the instruments, leading to a disinformation of which entity has the responsibility to take action in times of acute contamination; the rules do not address specific target groups, leaving the object of their effect and their area of action vague; also, concrete criteria – like limiting values for pesticides – along which one orients the measures are often missing (i.e. for maximum admissible values for surface waters). The Costa Rican IRR of water is thus complex: it has a great extent of diverse rules and guidelines defining water policy and a low coherence among these.

The integrated use of the two analytical approaches SESF and IRR has shown that they serve each other: the IRR facilitates an analysis of the institutions that shape a social-ecological system and the resource uses within it that goes far beyond the SESF's capacities to assess the SES's governance system. The IRR offers the lenses through which one "enters" and studies the SESF's element governance system: the assessment of both private property rights and public policies, its definition of different regulation modes, and its categorization of resource regimes based on the regulations' extent and coherence.
The analysis of the respective environmental problem with the SESF allows an in-depth *de facto* analysis of the situation the given institutional resource regime is meant

to manage, that the analytical IRR approach cannot provide in this intensity and concretion.

The combined application of SESF and IRR opens up ways for an extensive and thorough research on the nature of CPR problems and the ways in which they are regulated. To be more precise, IRR applications rely on a thorough understanding of the resource, the goods and services it provides, the actors who use these resources and which conflicts might arise from their use. By integrating both analytical frameworks, we provide a strict systematic lens through which the resource use situation as well as its regulation is investigated. So far, research has treated these different frameworks separately; we found that for this detailed case study, a more systematic and combined approach helps to disentangle the interdependencies between actions and rules.

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With this investigation we are not able to provide information or conclusions on how effective the regulation of a resource use situation is. The effect of policy on environmental outcomes is an endeavour we leave for future research. We can however answer whether resource use conflicts are addressed and where regulatory gaps persist. By using the SESF, we give credit to the scope of the case study design by understanding a socio–ecological system situation in depth. We use this knowledge about its different components to identify potential resource use conflicts. Once these conflicts are identified, we use the IRR to grasp the regulation of these user conflicts. The information about institutional strengths and weaknesses can be channeled back to the socio-ecological system to understand which parts of the system we need to understand better to design more effective policies and succeed in providing integrated resource management.

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6 Appendix

Table 2: Elements of the IRR (own elaboration, based on Knoepfel et al, 2007)

Property rights (PRs)	*Description*	*Examples*
Formal property title	Definition of property used by the society	– Private – Collective
Disposal right	Right to sale, to gift, rental, etc.	Right to sale, to gift, rental, etc.
Use right	Right to construct on, deposit, use, protect, etc.	Right to construct on, deposit, use, protect, etc.
Public policies (PPs)	*Description*	*Examples*
Definition of the collective problem and the objective	Environmental policy is often based on successive interpretations and definitions of collective problems	– Threats to public health – Pollution of water bodies – Diffuse pollution of surface and underground water bodies (agricultural run offs)
Causal hypothesis and target groups	Logics of intervention based on a rationale relating a specific group to the creation of the problem; provides an answer to the question as to who/what is guilty	– Industry is responsible for toxic disposal in waste water – Agriculture is responsible for contamination of soil due to pesticide use – Households use pesticides for the control of insects
Intervention hypothesis and instruments	Modes of intervention believed to be capable of producing the desired changes in the behaviour of the target group/s	Differentiation between various instrument types: – Regulatory (e.g.pesticide restrictions on certain active ingredients) – Economic (tax or subsidies) – Persuasive (guidelines on best agricultural practices)
Institutional coordination	Responsibilities are clearly defined and distributed	– Responsibilities are overlapping – One main organ of coordination is identified

Table 8: List of restricted or prohibited active ingredients Costa Rica (until 2015)

Active ingredient	Act number	Organization	Condition	Transitory disposition	Year
Acetate Dinoterb	31997	MAG, MS	Prohibition	-	2004
Acetate Medinoterb	31997	MAG, MS	Prohibition	-	2004
Acetate Phenylmercuric	31997	MAG, MS	Prohibition	-	2004
Acidos Fluoracéticos	31997	MAG, MS	Prohibition	-	2004
Acrylonitrile	31997	MAG, MS	Prohibition	-	2004

Table 8: List of restricted or prohibited active ingredients Costa Rica (until 2015)

Active ingredient	Act number	Organization	Condition	Transitory disposition	Year
Alachlor	38677	MAG, MS, MTSS, MINAE	Prohibition	-	2015
Aldicarb	38678	MAG, MS	Prohibition	-	2014
Aldrin	27773	MAG, MS, MTSS	Prohibition	-	1999
Alfa-Naphthylthiourea	31997	MAG, MS	Prohibition	-	2004
Aluminum Phosphide	34146	MAG, MS, MTSS, MINAE	Sale under professional recipe	-	2007
Aminocarb	31997	MAG, MS	Prohibition	-	2004
Amitrole	31997	MAG, MS	Prohibition	-	2004
Anabasine	31997	MAG, MS	Prohibition	-	2004
Aramite	31997	MAG, MS	Prohibition	-	2004
Arsenic with (Pb, Ca, Mg, Mn, Fe, Inorganic Arsenic)	27774	MAG, MS	Prohibition	-	1999
Bromacil	40423	MAG, MINAE	Prohibition	-	2017
Cadmio Based Compounds (Salts And Derivatives)	31997	MAG, MS	Prohibition	-	2004
Captafol	27767	MAG, MS	Prohibition	-	1999
Carbofuran	38713	MAG, MS, MTSS, MINAE	Prohibition	It authorizes its use in granular formulations for pineapple and banana crops in which use it is authorized until 12.04.2016.	2014
Carbon Disulphide	31997	MAG, MS	Prohibition	-	2004
Carbon Tetrachloride	31997	MAG, MS	Prohibition	-	2004
Chloranil	31997	MAG, MS	Prohibition	-	2004
Chlordane	27773	MAG, MS, MTSS	Prohibition	-	1999
Chlordecone	27773	MAG, MS, MTSS	Prohibition	-	1999
Chlordimeform	27773	MAG, MS, MTSS	Prohibition	-	1999

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Active ingredient	Act number	Organization	Condition	Transitory disposition	Year
Chlorofluorocarbons	35676	MAG, MS ,MTSS, MINAE, MH	Prohibition	-	2009
Chloroform	31997	MAG, MS	Prohibition	-	2004
Chlorpyrifos	34142	MAG, MS, MTSS, MINAE	Unicamente se autoriza el uso terrestre de los productosque contengan clorpirifos en los cultivos autorizados por el Ministerio deAgricultura y Ganaderia, respetando las zonas de protecci6n del habitatacuatico estipuladas en el articulo 33 de la ley 7575 "Ley Foresta"""	-	2007
Cianoga	Law 2641	Parlament	Prohibition	-	1960
Creosote	31997	MAG, MS	Prohibition	-	2004
Crimidine	31997	MAG, MS	Prohibition	-	2004
Cyanide-Based Compounds (Salts And Derivatives)	31997	MAG, MS	Prohibition	-	2004
Cycloheximide	31997	MAG, MS	Prohibition	-	2004
Cyhexatin	27772	MAG, MS	Prohibition	-	
Daminozide	21161	MAG, MS	Sale under professional recipe	-	1992

Table 8: List of restricted or prohibited active ingredients Costa Rica (until 2015)

Active ingredient	Act number	Organization	Condition	Transitory disposition	Year
Ddt	27773	MAG, MS, MTSS	Prohibition	-	1999
Dechlorane	27773	MAG, MS, MTSS	Prohibition	-	1999
Demeton	31997	MAG, MS	Prohibition	-	2004
Demotion	31997	MAG, MS	Prohibition	-	2004
Dialifor	31997	MAG, MS	Prohibition	-	2004
Diazotrophs	31997	MAG, MS	Prohibition	-	2004
Dibromochloropropane	27773	MAG, MS, MTSS	Prohibition	-	1999
Dichlorophenoxy Propionic (2,4-Dp)	31997	MAG, MS	Prohibition	-	2004
Dieldrin	27773	MAG, MS, MTSS	Prohibition	-	1999
Dimefox	31997	MAG, MS	Prohibition	-	2004
Dinitrocresol	31997	MAG, MS	Prohibition	-	2004
Dinoseb And Dinoseb Salts	27773	MAG, MS, MTSS	Prohibition	-	1999
Dinoterb	31997	MAG, MS	Prohibition	-	2004
Dioxin (2,4,5-T, 2(2,4,5-T)P)	17486	MAG, MS	Prohibition	-	2004
Di-Trapex	31997	MAG, MS	Prohibition	-	2004
Dodecachlor (Dodecachlor Penta Cyclodecane, Mirex)	31997	MAG, MS	Prohibition	-	2004
Endosulfan	38834	MAG, MS, MTSS, MINAE	Prohibition	Authorized in coffee cultivations, to control the coffee berry borer, Hypothenemus hampei, authorizes use until 30.03.2017.	2015
Endrin	27773	MAG, MS, MTSS	Prohibition	-	1999
Epn	31997	MAG, MS	Prohibition	-	2004
Ethyl Azinphos	31997	MAG, MS	Prohibition	-	2004
Ethyl In Dibomur	27773	MAG, MS, MTSS	Prohibition	-	1999
Ethyl Parathion	31997	MAG, MS	Prohibition	-	2004

Table 8: List of restricted or prohibited active ingredients Costa Rica (until 2015)

Active ingredient	Act number	Organization	Condition	Transitory disposition	Year
Ethylene (Ethephon)	27768	MAG, MS	Prohibition use in cofee. For other crops monitoring by MAG.	-	1999
Ethylene Dichloride	31997	MAG, MS	Prohibition	-	2004
Ethylene Oxide	31997	MAG, MS	Prohibition	-	2004
Etoprofos	34141	MAG, MS, MTSS, MINAE	Prohibition for aerial application	-	2007
Fenoprop (2,4,5-Tp)	31997	MAG, MS	Prohibition	-	2004
Fensulfothion	31997	MAG, MS	Prohibition	-	2004
Fluenetil	31997	MAG, MS	Prohibition	-	2004
Fluoracetamide	31997	MAG, MS	Prohibition	-	2004
Fosacetin	31997	MAG, MS	Prohibition	-	2004
Heptachlor	27773	MAG, MS, MTSS	Prohibition	-	1999
Hexachlorobenzene (Hcb)	31997	MAG, MS	Prohibition	-	2004
Isobenzan	31997	MAG, MS	Prohibition	-	2004
Isodrin	31997	MAG, MS	Prohibition	-	2004
K-Detrina	31997	MAG, MS	Prohibition	-	2004
Kelevan	31997	MAG, MS	Prohibition	-	2004
Leptophos	31997	MAG, MS	Prohibition	-	2004
Lindane	27773	MAG, MS, MTSS	Prohibition	-	1999
Mecarban	31997	MAG, MS	Prohibition	-	2004
Mercuric Chloride	31997	MAG, MS	Prohibition	-	2004
Mercury	27769	MAG, MS	Prohibition	-	1999
Methomyl	34145	MAG, MS, MTSS, MINAE	Sale under professional recipe	-	2007
Methyl Parathion	34140	MAG, MS, MTSS, MINAE	Prohbition emulsifiable concentrate.	-	2007
Mevinphos	31997	MAG, MS	Prohibition	-	2004
Mexacarbato	31997	MAG, MS	Prohibition	-	2004
Monocrotophos	34144	MAG, MS, MTSS, MINAE	Prohibition	-	2007

Table 8: List of restricted or prohibited active ingredients Costa Rica (until 2015)

Active ingredient	Act number	Organization	Condition	Transitory disposition	Year
Morfamquat	31997	MAG, MS	Prohibition	-	2004
Nicotine Sulfate	31997	MAG, MS	Prohibition	-	2004
Nitrofen	27773	MAG, MS, MTSS	Prohibition	-	1999
Obsolete Pesticides	31997	MAG, MS	Prohibition	-	2004
Omethoate	31997	MAG, MS	Prohibition	-	2004
Organochlorine	18451	MAG, MS	Prohibition on animals	-	1988
Paraquat	34139	MAG, MS, MTSS, MINAE	Sale under professional recipe	-	2007
Pentachlorophenol (Hxcdd)	27773	MAG, MS, MTSS	Prohibition	-	1999
Phosphamidon	31997	MAG, MS	Prohibition	-	2004
Poison Pesticides With Highly Dangerous Classification And Extremely	33495	MAG, MS, MINAE, MEIC	Sale under professional recipe	-	2007
Prothoate	31997	MAG, MS	Prohibition	-	2004
Schradan	31997	MAG, MS	Prohibition	-	2004
Sodium Cyanide	31997	MAG, MS	Prohibition	-	2004
Sodium Fluoroacetate	27773	MAG, MS, MTSS	Prohibition	-	1999
Strychnine	31997	MAG, MS	Prohibition	-	2004
Sulfotep	31997	MAG, MS	Prohibition	-	2004
Sulprofos	31997	MAG, MS	Prohibition	-	2004
Talio Based Compounds (Salts And Derivatives)	31997	MAG, MS	Prohibition	-	2004
Tepp	31997	MAG, MS	Prohibition	-	2004
Terbufos	34143	MAG, MS, MTSS, MINAE	Sale under professional recipe	-	2007
Terpenes-Polychlorinated (Strobano)	31997	MAG, MS	Prohibition	-	2004
Thallium Sulphate	31997	MAG, MS	Prohibition	-	2004
Tionazin	31997	MAG, MS	Prohibition	-	2004
Toxaphene	27773	MAG, MS ,MTSS	Prohibition	-	1999
Vinyl Chloride	31997	MAG, MS	Prohibition	-	2004
Zinc Phosphide	31997	MAG, MS	Prohibition	-	2004

Table 4: In-depth interviews conducted in 2015

Number of interview	Date of interview	Role	Name of organization
Interview 1	May 8, 2015	Expert	Secretaria de sustancias químicas, Dirección Gestión de Calidad Ambiental (DIGECA), Ministerio de Ambiente y Energía (MINAE)
Interview 2	May 12, 2015	Director	Dirección de normativa y control, Instituto Costarricense de Acueductos y Alcantarillados (AyA)
Interview 3	May 14, 2015	Expert	Dirección de Protección de Ambiente Humano, Ministerio de Salud (MS)
Interview 4	May 15, 2015	Judge	Tribunal Ambiental Administrativo (TAA), Ministerio de Ambiente y Energía (MINAE)
Interview 5	May 20, 2015	Scientist	Instituto Regional de Estudios en Sustancias Tóxicas (IRET), Universidad Nacional de Costa Rica, Proyecto Biosfera

Table 6: Legal documents investigated in the IRR (status: 2015)

Name of legal document	Year of publication	Type of document	Domain
Constitución Política de la República de Costa Rica	1949	constitution	general
Agenda de Agua	2013	action plan/program	water
Ley general de salud	1973	law	health
Ley de biodiversidad	1998	law	environment
Ley general de agua potable	1953	law	water
Ley de Aguas	1942	law	water
Código Penal	1970	law	general
Reglamento para la calidad del Agua Potable	2015	ordinance	water
Modifica el Reglamento para la calidad del agua potable	2015	ordinance	water
Política Hídrica Nacional	2011	action plan/program	water
Plan Nacional de Gestión Integrada de los Recursos Hídricos	2008	action plan/program	water
Reglamento para la evaluación y clasificación de la calidad de cuerpos de agua superficiales.	2007	ordinance	water
Principios que regirán la política nacional en materia de gestión de los recursos hídricos	2002	ordinance	water
Reglamento del canon ambiental por vertidos	2008	ordinance	water
Ley Orgánica del Medio Ambiente	1995	law	environment
Ley Constitutiva del Instituto Costarricense de Acueductos y Alcantarillados	1961	law	water
Reglamento de Creación de la Dirección General de Gestión de Calidad Ambiental	2004	ordinance	environment
Reglamento Orgánico del Ministerio de Ambiente, Energía y Telecomunicaciones	2010	ordinance	environment
Reglamento de procedimientos del Tribunal Ambiental Administrativo	2008	ordinance	environment