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Enhancing Efficiency of Water Provision

Theory and Practice of Integrated Water Management Principles

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Abstract

One of the policy options to increase the efficiency in the provision of scarce water resources is a reduction in transaction costs in water chains by developing integrated forms of water management. Integrated water management in case of river basin areas may comprise inter alia: (1) increasing co-operation at the river basin scale, (2) establishment of a river basin authority for an efficient co-ordination of policy measures in the relevant area, (3) developing a coherent policy addressing the entire water chain, (4) integrated strategies regarding all water functions in relation to other relevant spatial and environmental functions, and (5) ‘water-as-ordering-principle’, where water functions are the binding constraints for any other competing spatial function in a river basin area. In this paper we discuss the different integrated water management concepts from a theoretical and practical point of view. Moreover, we will explore the potential of efficient integration on the basis of five European projects addressing river basin areas. We argue that the above concepts are from an economic perspective promising, but that external circumstances create barriers for meeting the objectives of integrated water management.

JEL-codes: Q25, Q28
Keywords: integrated water management, transaction costs, river basin authorities

1 Introduction

Water is not just a chemical-physical substance, but a critical part of our ecosystems. It is, therefore, no surprise that in both the literature on resource economics and in resource policy water has obtained a prominent role. Water is of vital importance for human existence. Around the world we witness many problems with water. Of all these problems, shortage of water is the most frequent. At many locations around the world there is at the same time an abundance of water, but its quality is insufficient to carry out certain usage functions. Furthermore, too much water (e.g. flooding) may threaten (economic) activities. Protection from an overabundance of water is the problem in this situation.

Throughout history, the allocation of water resources has been the subject of many disputes between, for example, countries or various user groups. A considerable number of these water disputes or problems with water are clearly visible in many developing countries. However, also in developed countries huge efforts are required to satisfy basic needs. Rapid population growth increases the need for greater efficiency of water use for consumptive and production purposes. The situation of water scarcity illustrates the constant need for a balanced supply of water, which poses several problems. These problems call for investments in infrastructure that enable us to store and regulate the supply of water. The stochastically determined rate of water supply results in an uneven distribution of water over certain regions in the world. It is, therefore, no surprise that public policy has traditionally had considerable influence on the (drinking) water sector; governments play deliberately an important role in the production of (drinking) water in most countries. However, in recent decades, the role of governments in water provision has been changing drastically. On the one hand, we can observe governments that are still heavily involved in the water sector, while, on the other hand, we observe governments gradually withdrawing from water provision.

Especially in the last decade, there has been an increasing interest in water issues. Some key issues that have been debated are related to the governance structures (the framework of institutions) of drinking water provision and possible taxes on water use. Recent years are also characterised by an important change in the perception of water. Starting with the Dublin Declaration in 1992 (International Conference on Water and the Environment, 1992), water is increasingly being considered as a normal economic good that is subject to the ordinary, basic and generally applicable laws of supply and demand. The debate also marks an important shift away from the traditional approach, in which the satisfaction of *any* level of demand was considered to be the primary objective of public actors. These debates tend to lack a well-structured economic analysis of water management and related decisions. There is still a fair amount of scepticism about the use of insights from economics for a policy analysis of the water sector. However, economists provide several options for economic instruments, such as the use of price instruments and economic policy measures such as changing governance issues of the water provision, for example, privatisation and liberalisation. In this paper we discuss the different integrated water concepts from a theoretical and practical point of view. Moreover, we try to give a first glance of the extent of integration with the help of five European projects on river basin areas.

This paper is organised as follows. In Section 2 we describe the different water functions and the various definitions that deal with the integration of water resources or water functions. We then discuss the development of past attempts to integrate water management, mainly from a perspective of drinking-water provision. Section 4 discusses the pros and cons of integrated water-chain management, while Section 5 extends the concept of integrated water management to include spatial planning. The widest expression of integrated water management, the 'water-as-ordering-principle', is explained in Section 6. Then, in Section 7 we analyse with the help of five different river basin projects the critical factors explaining the possibilities for integrated water management. Based on principles from artificial intelligence, a rough set analysis is then performed in order to identify the extent to which the projects satisfy the definitions of integration in policy measures. We offer in Section 8 conclusions and policy recommendations on the possibilities of using integrated water management as a tool to achieve sustainable water use.

2 Water Functions and Definitions of Integration

Water provides an interesting range of different user-possibilities and therefore different functions. Hueting (1974) distinguishes, for example, drinking water, water for industry, water for agriculture and water for recreation function, as shown in Table 1. Because of social developments such as population growth and increasing quantities of goods and services required per head of the population, these different functions often fail to meet growing needs. Some of these functions are essential to human life, others are less significant. To use these functions, for example, in combination with integrated water management, they have to be categorised. An important reason for categorisation is that most functions provide for different needs and require different qualities of water. This categorisation, developed by Hueting (1974), is shown in Table 1.

Table 1. The different functions of water

	Water functions
1	drinking water
2	water for industry
3	water for agriculture
4	water for recreation
5	water in the natural environment
6	transportation water (shipping)
7	water in the residential environment
8	water for construction
9	water for disposal

Because of growing use and pressure on water functions, there is a competitive relation between the functions. This can be seen as a loss of functions in that the use of one function has a negative effect on another. For example, the use of water for disposal has a negative effect on the function of drinking water. The effect can be based on the quantity or quality of that function. *Quantitative* competition occurs when one function completely excludes another function, e.g. drinking water cannot be used for agricultural purposes after it has been consumed. *Qualitative* competition occurs when one function reduces the usefulness of water for another function. Water used for agriculture may be useless as water for the natural environment because of, for example, the possible presence of toxins.

Decreasing water yields call for a more systematic integration approach to the problems on a river basin scale. Actions should focus on both the demand side and the supply side of water. The literature on the economics of river basin areas highlights three different issues which should be tackled in the integrated approach (Alcamo et al., 2000; Askari et al., 2001; Bakker et al., 2000 and Chakravorty et al., 2000): (1) reduction of losses should be strived for. Large engineering works such as artificial reservoirs do not increase the basin yield. Savenije (1995, 1996a, b) refers to the evaporation losses during the dry seasons; (2) water yield should increase. In this case there should be intensive efforts to increase the efficiency of water use from rainfall[1] and; (3) a decrease in water demand, for instance, by means of a more efficient use of (rain)water for agricultural production, is necessary. In addition to the last action, water demand policy on the various policy levels of relevant river basin areas should be developed in order to influence water demand.

A wide range of actors and activities continuously affects water resources. Priscoli (1990) calls for a high level of public involvement in disputes on water resources. The classical example in economic theory, describing the essence of the problem, concerns the fact that upstream polluting activities along a river have far-reaching consequences for the activities and functions downstream. Such effects are described in a classic article by Coase (1960). Coase argues that if the transaction costs between the affected and the affecting parties along the river (upstream and downstream) are negligible and bargaining can take place freely, efficient 'polluting' outcomes will be achieved by, for example, compensation for polluting activities. However, transaction costs in reality are not negligible (see, e.g., Williamson, 1985). The integration of various activities and experiences on international co-operation in a river basin area are extensively described by various authors in a number of settings. Interesting experiences on international co-operation in a European setting can be found in papers by Huisman et al. (1998), De Jong et al. (1989) and Mostert (1996). Experiences of river basin management planning in England and Wales are well described in a paper by Woolhouse (2001).

A solution to cope with downstream pollution if bargaining solutions do not work could be the introduction of a *River Basin Authority* (RBA) that co-ordinates the activities along the entire river. Additional reasons for the establishment of an RBA are given by Savenije et al. (2000) and De Jong (1998). They argue that sound reasons for the establishment of an RBA might be that: (1) the scale of (international) river basins is considerable and there is limited knowledge on system interactions, (2) there may be different interests within an (international) river basin which are not compatible, (3) there may be a considerable gap between policies, plans and practices, and (4) new developments may require entirely new regulations. The establishment of an RBA might be a useful instrument for the coordination and development of water policy in a river basin. One coordinating RBA can considerably enhance efficiency in the coordination of activities of stakeholders that are involved in water management. Increasing integration of and stimulating cooperation among the stakeholders may be a useful instrument. From an economic point of view, the establishment of an RBA may reduce transaction costs and increase the efficiency of water management.

In the Netherlands, integrated water-chain management is the result of a strengthening of a general trend towards the integration of different policy fields. In this way greater efficiency, more transparency and a better coordination can be achieved through a Water Board, which might lead, among others, to an *'integrated water bill'*, as is used in some countries (for example in Denmark). As well as the need for the integration of the different policy fields concerning water management, there appears to be a need for *improved cooperation* between water management authorities, municipalities and provinces to ensure greater coordination between the different types of plans. The result of this closer cooperation between municipalities and local Water Control Boards will be an increase in opportunities to reinforce the various functions of water in the urban area (e.g. by using grey water to create ponds in public gardens) and reduce any adverse effects on the surrounding area.

The Dutch Ministry of Housing, Spatial Planning and the Environment (HSPE) has proposed to go one step further than the national integrated water management policy. It advocates *'integrated water chain* *management'*, a coherent management of all elements in the water chain from source to sewage in order to increase efficiency in two ways. First, the water chain can be managed as a whole, and water policy measures can be implemented rapidly, because the implementation is carried out by one authority, which also decreases the transaction costs. Second, integration offers the possibility to make users aware of the water chain. One integrated water bill, e.g. linking water use with waste water production, can make users aware of these interconnections. However, regarding the practical implementation of integrated chain management in Amsterdam, several critical remarks can be made (Rodenburg et al., 2000). First, the sewage and the drinking water systems are currently completely separated. Integration and co-operation between the systems is envisaged to be a lengthy process with many obstacles, ranging from very practical ones to re-organisational difficulties caused by the often very different cultures and organisation modes in the different companies in charge of water management and supply. Second, operational problems exist due to the absence of water metering. This makes it impossible to charge people in relation to their actual use. For these reasons, the concept of integrated chain management is still the subject of debate and not yet implemented.

The concept of increasing integration can be implemented at various intensities, ranging from only an *integrated management of different water functions*, such as the drinking water function and water for recreation to *integration of water functions with spatial planning functions* or even water constraints as binding principles for other functions. This is often described as the 'water-as-ordering-principle' (Valk and Wolsink, 2001). Such increasing intensities of integration also lead to changes in the water supply chain. Most likely, certain organisations will join forces and start to jointly control the water quality. The degree to which this will happen depends partly on the results of the current political discussion on privatisation. If the water companies are privatised (horizontally), integration with other sectors (e.g. electricity, cable and telephone) will probably take place first.

3 A Practical Example of the Idea of a River Basin Agency

Although water quantity *per sé* is not a real problem in Amsterdam; there are always concerns about water quality. The River Rhine, which is used as a drinking water source for the Amsterdam Water Supply Company, suffers from pollution. The pollution in the Rhine largely derives from external sources (partly from other countries through which it flows before entering the Netherlands). High concentrations of chemical substances (high concentration of netazon and atrazine) emitted by factories located in Switzerland and Germany have frequently resulted in the situation that intake of water from the Rhine has had to be stopped. After a long period of lobbying and policy pressure by environmental organisations and the Amsterdam Water Supply Company, policy makers developed programmes and actions to improve the water quality of the Rhine.

An example of such a programme is a comprehensive programme with the title ‘Rhine Action Programme’, which was approved by the Rhine countries in 1987. The programme was designed to voluntarily decrease the pollution of the Rhine, with a general focus on the big polluters. The targets of the programme (for the year 2000) were: (1) the return of higher organisms (e.g. water-quality-sensitive salmon) in the river, (2) the sediment of the Rhine should be usable for many purposes, and (3) the Rhine should be a reliable drinking water source (Dalhuisen et al., 2000).

Over recent decades, the action plans have significantly improved the quality of the Rhine, substantially reducing the occurrence of emergency situations in which the water intake for drinking water purposes from the Rhine River had to be stopped. However, serious problems still exist. These problems especially arise from the presence of small polluters. Recent policy proposals have aimed at solving these problems by focusing on a stricter discharge policy for pesticides together with instruments to extend this policy in order to show the impacts of pesticide pollution to the users. Through efforts aimed at increasing awareness among small (diffuse) polluters, the government is attempting to bring a halt to the pollution of the Rhine. These past developments follow, although not fully, the line of the mandatory requirements of the Water Framework Directive of the European Union for integrated water management and integrated water resource management at a catchment scale.

4 Integrated Water-Chain Management

Integrated water-chain management is managing the water chain as a whole. From an environmental point of view there are various advantages. The main advantage is the fact that consumers recognise a linkage between water consumption and wastewater, because their water bill is also dependent on the level of waste water. Furthermore, consumers may become ultimately aware of a more coherent vision of the entire water chain, because by means of their water bill they link water consumption with waste water.

As stated earlier, there are various disadvantages of changing water provision along the lines of one water chain. As discussed in the literature on the economics of water resources, the capital intensity of the water industry is considerable (see also Bauman et al., 1998). The costs to move from the current situation to the integrated chain situation may be considerable, while the advantages are significantly lower. The probabilities that the elements of the water chain are geographically located far from each other are very high. Moving the elements closer to each other may involve high costs. Furthermore, the incentives of organisations in the water chain may vary as well. A water company may be a public one or part of the local authority, like in the case of Amsterdam, while the sewage company may be organised privately. The incentives of both organisations are different, for example, profit making versus maximisation of the public utility.

Bahri (2001) goes one step further in his article on urban and peri-urban water-related relationships. The author argues for closing the water loops. Agricultural systems should be integrated in the water chain for residential users, especially the sanitary systems that might be used for the agricultural systems as a way for nutrient recycling. This could ultimately result in a more soundly-based urban and peri-urban environment. However, various agents using those systems should establish all kinds of partnerships and their economic incentives should not differ too much.

However, the concept of integrated water chain management has various drawbacks. First, in practice, the elements of the chain are often located far away from each other. Second, there is no connection with other different spatial functions, such as agriculture and other economic activities. Nevertheless, there is sufficient reason to integrate the water chain, if the main policy goal is to make the user aware of the existence of the water chain.

5 Integrated Water Management and Spatial Planning

Spatial planning addresses the co-ordination of a range of spatial functions[2] of which one group are the water functions. In an integral approach, water functions can be managed by focussing also on the range of other functions.

One interesting study is the study of Bouwer (2000), who calls for the coordination of water functions with the overall water management of the region under consideration. Sustainability, public health and environmental protection are key factors in his article and are the leading principles for the integration of the different water systems. If certain functions cannot be carried out properly because of water shortages, water may be obtained from water stocks. In periods of a surplus of water, water must be stored and can then be used in periods of shortage. Or when space for storage of water is lacking or there is a continuous shortage of water, countries can save water by importing it from other countries in the form of products where water is a major input (such as agricultural crops). In the same way Massarutto (1999) describes the link between agriculture and water resources in particular with respect to the Italian water and agricultural systems. A more market oriented approach to the agricultural sector provides a good opportunity for reconducing actual patterns of impact of the agricultural sector on water resources — and aquifers in particular — to sustainability.

Integrated water management is a concept that seems a proper way to deal with the interconnection between water functions and other spatial functions. However, there is probably a hierarchic ordering of spatial functions. Water functions are often taken into account in the last phases of the spatial planning process (Van Zalinge, 1999). As a result of the spatial planning process water problems[3] occur because, from the proper water management point of view, the spatial planning process may be flawed.

6 The 'Water-As-Ordering-Principle'

In the process of spatial planning (e.g. the construction of a residential area or various infrastructure projects), water functions or probabilities of floods are often not taken into account in the planning process or taken into account only at the last stage of the planning process. Spatial planning without a proper analysis of the impact of the planning decision from a water management perspective has often resulted in a number of water related problems, such as floods or desiccation (van Zalinge, 1999).

To identify these problems, water managers have sometimes created a map (like the so-called '*waterkansen kaart'* in the Netherlands), showing the possibilities for a whole range of water and various other spatial functions. Water functions are the binding principle for every spatial planning principle. Nowadays, water managers are often only involved in spatial planning decisions at the last stage of the planning process. The study of Van Zalinge (1999) on the integration of spatial planning and water management decisions maps at the diverse problems associated with this integration. The author gives three main reasons for a problematic integration of spatial planning and water management. The first of these reasons concerns the differences in culture. Water managers and spatial planners differ in terms of language and planning culture (e.g. the contents of their job). A second issue is the difference in goals and interests that results in different preferences for the solution for the ordering of a spatial area. The third aspect that makes the co-ordination difficult is the difference in knowledge. Better co-ordination of planning decisions and the binding constraints of water functions will give opportunities for the spatial planning process and decrease the occurrence of water-related problems.

7 Assessing the Extent of Integration: An Experiment

7.1 Introduction

A number of possible ideas on integration have been proposed in various policy documents and water projects have been planned for several reasons but integration is feasible to different extents in these projects. Furthermore, in the literature little empirical evidence has been reported on the extent to which integration is satisfied. In this section, we carry out a small experiment, a rough set analysis, based on five projects in river basin areas in Europe[4]. Without claiming completeness, we try to detect the importance the background characteristics of the five cases. These characteristics are often mentioned in the literature on the water management and will likely have an impact on the extent to which the definitions of integrated water management are achieved. Moreover, we try to find patterns between characteristics and the levels of integration. The section is organised as follows. First, we will introduce the five cases. Second, the technique of rough set analysis will be outlined. We conclude with results and interpretation of the rough set analysis.

7.2 Introduction of the Five Cases

The five European river basin projects can be characterised on the basis of attempts to increase the performance of water functions. The level of integration, as described in the previous sections, may however, be considerably different.

Three projects in our experiment are characterised by movement of water from one place to another place. There is no concept of integration included, because an increase of water functions is overshadowed by a loss in water functions in the area of the original source. In a fourth project, decreasing flood probabilities by increasing space for the river can be seen as an attempt to satisfy the 'water-as-ordering-principle'. The fifth of these projects is characterised by attempts to integrate different water functions; so this can be seen as satisfying the integrated water management principle. We will offer here a concise review of our five cases.

1. Alqueva Dam, Portugal

The use of Alqueva Dam is mainly for the purposes of irrigation (an area of 110,000 ha) and also urban supply. A third purpose for the dam is electricity production. The Alqueva dam will be one of the biggest dams in the Iberian Peninsula and will result in the largest artifical lake in Europe with an area of 250 km^2 and a capacity for 4150 hm^3 of water. The Alqueva is planned to be a large dam with 152m of maximum water level.

2. River Evinos Reservoir, Greece

The reservoir under construction at Agios Dimitrios in the valley of River Evinos draws from a catchment of 350 km^2 of a total river basin of 1,111 km^2. The maximum design volume capacity of the River Evinos Reservoir is 140 Hm^3. However, there is also an extensive sedimentation build-up from the Evinos (about 355.000 tonnes/yr) and a volume of up to 27 Hm^3 is expected to be lost. The surface area of the reservoir is 3.5 km^2. The project design study estimates an annual run-off to the reservoir of about 11.2 m^3/s (350 Hm^3). More recent revised hydrologic measurements have estimated a water inflow of 9.3 m^3/s (about 290 Hm^3/year). Analysis of hydrologic data during a recent period of drought decreases the estimates to an annual safe yield of about 200 Hm^3.

3. River Ebro Interbasin Water Transfer, Spain

The water transferred will be applied to irrigation, urban supply and environment restoration. Water will be transferred from the Ebro river basin to the Mediterranean coast (from Barcelona to Almeria). The project is the central issue in the Spanish National Hydrological Plan. The project's goal is to reach a general water balance in Spain. The project is a large-scale project and includes two canals with a total length of 900 km and a water transfer of 1,050 hm^3/year.

4. River Meuse, the Netherlands

The water project concerns protection against flooding, the development of a large natural area (1000 ha) and the commercial winning of gravel. The project follows the Meuse River at a length of 45 km between the places Maastricht and Roosteren in the provinces of Limburg. There is also cooperation with the Belgium authorities. It started in 1992 with an intention declaration between province of Limburg, Ministry of Housing, Spatial Planning and the Environment, Ministry of Agriculture, Nature Management and Fisheries and the Ministry of Transport, Public Works and Water Management (V&W) and will end in 2015. The project started with an experimental project near Meers.

5. River Ythan Nitrate Vulnerable Zone, Scotland

The Ythan estuary is a bird reserve of international conservation importance. The estuary is classified as a Special Protection Area (SPA) under the EC Birds Directive (79/449/EEC) and designated as a Ramsar site under the Convention on Wetlands of International Importance. The conservation quality of the site is under threat due to the nitrate-related eutrophication leading to NVZ designation in line with the criteria set out at Annex IA (3) of the EC Nitrates Directive, i.e. the estuary is eutrophic or in the near future may become eutrophic. High nitrate levels were attributed to increased amounts of fertiliser and animal manures applied annually on farms in the catchment.

7.3 Introduction to Rough Set Analysis

Rough set analysis is a recently developed nonparametric statistical method. For an extensive theoretical description we refer to Pawlak (1991) and Slowinski (1992). Examples of applications of rough set analysis to environmental economic issues can be found in Van den Bergh et al. (1997), Nijkamp (2000a, b) and Masurel et al. (2001). These applications relate *inter alia* to pesticide use in agriculture, urban land use policy, transportation policy and performance of ethnic entrepreneurs.

A set for which the classification of a group of certain objects is uncertain can be characterised as a rough set. The classification of categorical information is then dependent on the degree of 'granularity'.

In the theory of rough sets, we assume the existence of a certain finite set of objects to be classified. The information is gathered in terms of the assignment of relevant attributes of the river basin projects to distinct classes (e.g. kind of water problems observed) or in terms of factual knowledge (e.g. the time scale). An attribute and a coded value of this attribute can express each of these properties. Since the classification is not straightforward, we have a case of rough sets. The extent to which the definitions of integrated water management are achieved can be described as a set D:

$$\mathrm{D} = \{\mathrm{X}^{\mathrm{n}}\},$$

with n the project under consideration and X the belonging background characteristics. The reasons for –and the extent of — the integration of water management are incorporated in the decision variable (D), and there are three different categories. Table 2 shows all the variables used in this rough set analysis and their corresponding coded variables, as well as the categories of the decision variable.

Table 2. Categorisation of background factors to explain the extent of integration

Categories	Attribute Values
Levels involved (Le)	1. European and national 2. National and local
Location (Lo)	1. North Europe 2. South Europe
Scale (S)	1. Large 2. Medium 3. Small
Physical characteristics of the project (P)	1. Dam, channels and reservoirs 2. Non-artificial changes
Water problems (W)	1. Quality-oriented problems 2. Quantity-oriented problems
Time scale (T)	1. Long term 2. Short term
Decision variable (D)	1. Movement of water 2. Attempts to satisfy 'water-as-an-ordering-principle' 3. Integration of water functions

For each attribute we have the relevant sets with the corresponding scores or codes of these attributes. An important variable to classify the degree of satisfying the various water management levels is the project scale, we may have a set V of values of these attributes. The characteristic set may be $V_s = \{1,2,3\}$, where V_s refers to the attribute 'project scale (S)', which can be represented by three values: 'large' (code 1) or 'medium' (code 2) or 'small' (code 3). Other relevant sets may be $V_{Le} = \{1,2\}$, where V_{Le} refers to the attribute 'Levels involved (Le)', which can be represented by two values: 'European and National' (code 1) or 'National and Local' (code 2) and $V_T = \{1,2\}$, where V_T refers to the attribute 'Time scale (T)', which can as well be represented by two values: 'Long Term' (code 1) or 'Short Term' (code 2).

As shown in Table 2, there are various other important (explaining) attributes. The levels involved (Le) might be important, because they show a policy orientation towards a more integrated concept of water management. The location (Lo) is included, because places in the south of Europe may be, in general, places having problems with water quantity, so there might be increasing incentives for artificial water reservoirs or movement of water. The scale (S) is of utmost importance, because small-scale projects may result in less efforts being made for the integration of water management. The river basin scale is in the study by Gilbert et al. (1998) mentioned as an important element for a more integrated approach of water resources. The physical (P) variable is included because of the fact that with artificial solutions (e.g. dams), it is difficult to achieve a degree of integration, while this is not the case by changing parts of the landscape and giving more space to rivers. Water problems (W) are included because of the particular nature of the problems. In Scotland the problem is qualitative and in the other places quantitative. A time-scale variable (T) is included because of the dynamics of the problems. Table 3 shows the coded data matrix for the five projects, based on the information of the five cases and the categorisation of background factors (see Table 2).

Table 3. The coded data matrix for the five projects

Country	Case	Le	Lo	S	P	W	T	D
NL	1	2	1	2	2	1	1	2
UK	2	1	1	3	2	2	2	3
GR	3	2	2	2	1	1	2	1
P	4	1	2	1	1	1	2	1
ESP	5	1	2	1	1	1	1	1

NOTE: NL: the Netherlands - — UK: United Kingdom — GR: Greece — P: Portugal — ESP: Spain

The attributes may be used to define an equivalence relationship:

$$D \rightarrow P(Le, \ldots S \ldots T).$$

This can be interpreted as follows: the level of satisfying the various definitions of integrated water management depends on various institutional attributes, such as the level involved in the project, spatial scale attributes and time scale attributes. Objects belonging to the same equivalence classes, based on the features concerned, are indiscernible. In the case of multiple attributes, the intersection of the attributes results in equivalence relationships that lead to a more precise classification than in case of a single equivalence relationship. The reduct is then a subset of all attributes. Adding other attributes to the reduct does not result in a more precise classification and deleting an attribute of the reduct will result in a less precise classification of the objects under consideration. Sometimes we find an attribute belonging to the core of a set. The core is the class of all indiscernible equivalence relationships. The combination of attributes and classes of projects can be regarded as a decision table.

Next, on the basis of the above information table with conditions (comprising variables such as, in our case, the characteristics of the projects) and the decision attributes (or classes of satisfying various definitions of integrated water management), we are able to construct decision rules (of an 'if…then' nature), which represent an implicit relationship between the background variables of projects and classes of satisfying definitions of integrated water management. The strength of the indicator might be explained with the help of the frequency of the indicator or attribute in each decision rule. If certain attributes occur frequently in the same decision rules, they have a considerable impact on the performance indicator characterising the water policy of the case city and can hence be considered as a critical factor.

The rough set analysis is carried out with the help of the computer program Rough Set Data Explorer (ROSE).[5] The algorithm of this programme constructs the best possible decision rules to classify the satisfaction of different integrated water management definitions. The decision rules are of an "if…then" nature and are constructed on the basis of the attributes given. For further details on rough set analysis and the software used we refer to the references given above.

7.4 Results and Interpretation

Table 4 shows the minimum sets of the rough set analysis carried out in our study. Although this is a small experiment, there are three particular variables which are important in the classification. The location is a variable that appears in 40 percent of the minimum sets and points for handling the integration of water management issues. The physical characteristics of a project is of equal importance and so is the time period. There is only a movement of water from one place to another. The scale of the project is a second important variable. Large-scale projects makes an integrated concept difficult, as is shown in the third decision rule. Local and national policy levels are involved, and if the river basin is located in the Northern part of Europe, this makes satisfying the 'water-as-an-ordering'-principle possible. Sufficient water is an important aspect, when policy makers want to satisfy a level of integrated water management.

Table 4. Minimum sets and frequencies of attributes

	Minimum Set	Variable	Frequency (percentage)
1	{Le, Lo}	Le	3 (30)
2	{Lo, S}	Lo	4 (40)
3	{Le, P}	S	3 (30)
4	{S, P}	P	4 (40)
5	{Lo, W}	W	3 (30)
6	{P, W}	T	4 (40)
7	{Le, W, T}		
8	{Lo, T}		
9	{S, T}		
10	{P, T}		

Table 5. Decision rules

rule 1. (Lo = 2) => (D = 1)
rule 2. (Le = 2) & (Lo = 1) => (D = 2)
rule 3. (S = 3) => (D = 3)

Table 5 presents the decision rules of our rough set analysis. The decision rules show some interesting features. The location is of considerable importance. In the Southern part of Europe, there is general low water availability, and possibilities for an integrated approach can be detected in the decision rules. The second decision rule shows that co-operation on two different levels in Northern Europe might result in satisfying to a certain extent ‘water-as-an-ordering-principle’. The third decision rule shows that small scale projects makes an integration of water functions easier because of a low number of water functions. These findings appear to confirm our theoretical-conceptual notions on integrated water management.

8 Conclusions and Policy Recommendations

International voluntary cooperation, with polluters, as in the case of Amsterdam, has resulted in water of increasing quality. We argued that cooperation was a favourable development for Amsterdam to improve the water quality of the Rhine. The introduction of an RBA, with legislative and controlling power, could be an important next step to increase the water quality of the Rhine River, because it decreases the transaction costs of various agents involved with water policy in the river basin area. At a national level, integrated water chain management has some promising potential in terms of decreasing transaction costs and increasing consumer awareness with respect to the water chain. Relevant practical problems are associated with the diverse governance structures that characterise the existing parties which are involved. Furthermore, integration seems to be incompatible with an alternative discussion and trend favouring privatisation. Different ownership-structures (e.g. public versus private) make integration in the water chain difficult, because each of the elements are guided by different incentives (e.g. profit-making versus a non-profit-making incentives).

Integrated water management is a promising idea, but the physical and institutional circumstances may raise considerable barriers for the execution of the idea. Countries with a more favourable physical and hydrological circumstances can, up to a certain scale, more easily satisfy the integrated water management or 'water-as-an ordering-principle' concept.

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[1] This shows a recognition of the importance of dryland agriculture compared with irrigation.

[2] In this context we may also refer to ‘functional zoning’ of land use. Land use zoning became a popular tool to separate different functions, such as the residential function from the industrial function, where the functions are incompataible (Haughton and Hunter, 1994).

[3] Such as increasing the probabilities of the occurrence of floods, dehydration or desiccation.

[4] The five projects are subjects of case studies that are part of the ADVISOR-project sponsored by the EU. The purpose of ADVISOR is to develop an integrated evaluation methodology for sustainable river basin governance.

[5] For more information: http://www-idss.cs.put.poznan.pl/rose/