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The Degradation of the Water Resources of the Urban Community of Fez: An Economic and Environmental Cost

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ABSTRACT

The protection of water resources is based on knowledge of the causes and consequences of environmental damage. It also calls for the development of strategies and the adoption of technologies to avoid it. However, this descriptive component, which focuses on the adoption of new "clean" technologies, offers no tools to guide decisions or to inform whether the actions undertaken are or are not efficient and profitable. The Meso-economic-environmental studies take this situation by evaluating the environmental damage and inefficiencies, the costs necessary to remedy them. To do this, it is necessary firstly to collect data and statistics. Secondly, the conversion of physical units into monetary ones using the economic methods of evaluation. Finally, estimating a relationship between the benefits and costs of remediation actions and identifying the priorities for decision-making. As part of the Meso-economic-environmental assessment of the water resources of the urban community of Fez, the cost of degradation of the water resource and inefficiencies in the use of this precious property is estimated at 2,087% of the added value (VA) of the city of Fez. The remedial actions recommended for the improvement of the quality of life, the preservation of the natural capital and the better management of the water resources are 1.398% of the VA of this urban commune. Deployment to implement remedial actions for the preservation of water resources are beneficial in the long term. In monetary terms, for every 1 MAD spent on remediation, 1.49 MAD damage will be avoided. In short, the Meso-economic-environmental assessment is an integrated approach that not only allows the monetarization of impacts and the identification of the most appropriate remedial actions but also combines urban development, respect for the environment and well-being of the population.

INTRODUCTION

Because of its geographical position, Morocco is a country with essentially arid to semi-arid climate, marked by spatio-temporal irregularities of the regime of its precipitations. As a result, average rainfall across the country is decreasing from northwest to southeast. The city of Fez by its location in the enter of the country and its joint ownership with well-watered areas of the Rif in the north and the Middle Atlas in the south-east benefits from a good water supply. However, the water resources at the level of this city are under pressure from consumer and waste-generating activities. In fact, the significant demographic evolution, the socio-economic development of the city and the change in lifestyle and consumption of the population, are at the origin of these significant pressures on water resources both quantitatively and qualitatively. In other words, the demand for water is not the only pressure on water resources; wastewater and domestic solid waste remains are also a very significant threat to surface water (Oued Sebou and Oued-Fez) and the water table (Fez-Meknes) that is already affected by pollution.

Despite the remarkable progress of the city of Fez in the field of environmental protection, specifically water resources, including the realization of the treatment plant and the controlled landfill, serious negative impacts on health, quality of life, as well as the economy of the cities are still generated by industrial and artisanal activities, in addition to the strong urbanization. The combination of these last factors inevitably leads to an over-exploitation of water resources and the degradation of their qualities. Although the extent of persistent problems is generally known, the monetary quantification of these impacts has remained completely unknown today.

The decision to make this study comes to overcome this lack, by determining the monetary value of water degrada-

tion and inefficiencies in the use of the latter through three economic categories: "Health and Quality of Life", "Natural Capital" and "Inefficiencies in Resource Utilization". And then identifying remedial actions that can avoid these degradations and inefficiencies and evaluating their respective costs. Estimating the relationship between the benefits and costs of remediation actions helps to identify priorities for decision-making.

MATERIALS AND METHODS

In this work we have adopted the methodology of Pillet & Zein (2004), Pillet (2006) and Maradan & Zein (2008a).

Principles of the meso-environmental analysis: The Meso-economic analysis proposes the responses at the level of the economic sector or the urban community, intermediate between the traditional micro and macro-economic dimensions. The Meso-economic scale is relevant because it focuses either on the type of activity of production, or on a well-defined urban community, as it is the case in this article, where we will present the water domain results only.

The Meso-economic analysis can be oriented in two distinct ways. It can first assess the profitability of a remediation action and thus identify the actions to be undertaken in priority (determination of A/C ratios). Secondly, it is also likely to explore the economic consequences of development and remediation strategies or their absence. In both the cases, quantifying the environmental damage and inefficiencies of an activity, which means measuring the environmental cost they inflict on the population and the economy, complements the traditional economic analysis; increasing the information available to decision-makers.

Definitions: The Meso-economic analysis deals with the quantification, in monetary terms and on an annual basis, of the cost of damages and inefficiencies (CDI) resulting from an economic sector and the cost of their remediation. Finally, these values are expressed in relation to the value added (VA) of the entity concerned.

***Damage Costs*:** In economic terms, damage refers to both welfare losses (suffered by the population) and financial losses (incurred by economic activities) as a result of the modification. The quality of the environment and the availability of environmental inputs.

***Cost of inefficiencies*:** Inefficiencies in resource use refers to the economic losses generated by waste or inefficient use of these resources. These losses include, for example, excessive leakage of water in distribution systems, lack of energy savings and avoidable losses of materials in production processes.

***Remediation Costs*:** Remediation costs for environmental degradation and inefficiencies represent the necessary expenditures, based on available knowledge and data, to protect the environment by preventing or remedying its degradation.

***Benefit/Cost Reports (CDI/CR)*:** Comparing these benefits and costs, in the form of a ratio, amounts to linking CDI and CR, as an approximation of the more general Benefit/Cost ratio. An economically efficient remediation action would imply that the total benefits outweigh the costs, in other words, the B/C ratio is greater than unity. It is also said that this ratio measures the profitability of remediation.

A ratio of 2 indicates that for 1 MAD invested in remediation, a loss equivalent to a welfare loss of 2 MAD is avoided.

Categories of analysis: The economic assessment of environmental degradation is structured according to seven environmental domains (water, air, noise, soil/littoral and landscapes, waste, energy/materials and global environment) and three economic categories (health/quality of life, natural capital, inefficiencies in resource use).

Steps of the analysis: Meso-economic studies are built on the basis of an analysis protocol comprising four steps.

***First step-Delimitation of the study area*:** First, the geographical perimeter is the urban community of Fez, and the environmental flows necessary for the functioning of the different actors are listed and quantified in their physical dimension. Unlike traditional economic analysis, emigration flows and the generation of externalities are taken into account. Emeralds refer to resources drawn freely from the environment, that is, from the environment contributing to the production process. This is, for example, water used by the production process. Externalities refer to the off-market effects of pollution of all kinds.

***Second step-data collection*:** The data are collected from the field visits, and the collaboration of specialists and managers of the sectors involved in the protection of water resources.

***Third step-eco-environmental analysis*:** This involves converting the environmental flows measured in physical units into monetary units. This conversion and the methods of economic evaluation of the environment that it requires, constitute the economic-environmental analysis. The analysis is based on the data collected, the definition of proxies (when data are missing) and the use of expert opinions. CDI and CR are related to the value added of the urban community (GDP). This third step leads to the monetary assessment of environmental damage and remediation. Finally, the B/C ratios, which facilitate the interpretation and understanding of the results, are calculated.

RESULTS

The results of our work are presented according to the economic categories affected by the pollution of the water resources of the urban commune of Fez (Reference year of the 2014 analysis).

Damages and Inefficiencies (CDI)

In the urban community of Fez, the water used for the various activities of the city comes from the water table Fez-Meknes and Oued Sebou. It is distributed by the RADEEF.

They are mainly the health of the population as well as the natural capital of the region that will suffer the consequences not only of the pollution generated by leachates and untreated sewage, but also inefficiencies during the transport, distribution and also the use of water.

Health and quality of life: Poor water quality, lack of hygiene and low percentage of non-connection to drinking water and sanitation are responsible for waterborne diseases that can be particularly fatal for children as well as adults.

The assessment of this damage due to waterborne diseases is based on the mortality and morbidity statistics of children under 5 years and also subjects over 5 years. This damage represents a cost for individuals, their families and society in general. To evaluate these costs, we use the cost of treatment and the financial loss (nurses, parents prevented from working).

In this study, we treat the costs related to typhoid and diarrhoea that represent diseases that are directly related to water quality.

***Typhoid*:** According to the health delegation of Fez the number of cases of typhoid is 23 cases, and 5000 MAD is the cost of treatment estimated by a specialist doctor in more than 30 days of rest for each case. Based on the cost of treatment and the hourly minimum wage of 12.24 MAD (Croitoru & Sarraf 2017), for a daily working time of 8 h the annual cost is estimated at 0.18 million dirhams, that is 0.0004% of the VA.

***Diarrhoea*:** For the mortality and morbidity related to diarrhoea in children and adults, due to lack of data, we have followed the approach used by the World Bank, which uses values at the national level, which we will apply to our city Fez.

***Mortality of children under 5 years*:** In Morocco, the mortality rate for this age group has decreased considerably in recent decades, from 138 per thousand in 1979 to 30.5 per thousand in 2011 and 28 per thousand in 2014 (Croitoru & Sarraf 2017). In addition, the percentage of mortality cases due to diarrhoea has decreased significantly, from 9.7% in 2000 to 5.4% in 2013 (Croitoru & Sarraf 2017). Not all diarrheal diseases are attributable to water pollution. Recently, WHO (2014) has estimated that waterborne determinants account for 50% of diarrhoea deaths in Morocco (Croitoru & Sarraf 2017). As a result, 74 deaths are recorded for each infant population of 97862 (Haut commissariat au plan 2015) in the city of Fes.

The estimate of the costs related to child mortality is calculated on the basis of the Value of Statistical Life (VSL) (Croitoru & Sarraf 2017). In Morocco, it has been estimated between 1.5 and 1.7 million dirhams, or 1.6 million dirhams on average. On this basis, the annual losses due to diarrheal deaths in children are estimated at 118.4 million dirhams, or 0.14% of the VA.

***Mortality of persons over 5 years of age*: WHO statistics (2014)** indicate 800 deaths from diarrhoea in this category in Morocco, from which only 50% of these cases are attributable to inappropriate practices related to water, this corresponds to 400 deaths in Morocco in the same year (Croitoru & Sarraf 2017). And so 10 deaths in the city of Fez. On the same basis of VSL, annual losses due to diarrheal deaths in this category were estimated at 16.2 million dirhams, or 0.037% of the VA.

***Morbidity in children under 5 years*:** Our estimation of morbidity losses is based on the value of years of life experienced with disability (AVI), developed by WHO. This concept is based on the fact that a mild disease represents a small fraction of an AVI, while a more severe disease represents a significant fraction of an AVI (Croitoru & Sarraf 2017). Thus, the total annual losses due to morbidity in children are encrypted at 183.12 AVI. We estimate the cost of morbidity based on the monetary value of an AVI, which is the PIB per capita equivalent to 20498 MAD. Added to this is the cost of treatment, which is based on the direct expenses incurred to treat sick children. As a result, the cost of morbidity due to diarrheal diseases in children is 18.67 million dirhams. That is 0.043% of the VA.

***Morbidity in persons over 5 years of age*:** OMS statistics (2014) (WHO 2014a) indicate 21000 AVI due to diarrhoea in persons over 5 years of age. Estimating that only 50% of these cases are attributable to the water determinants of health, this corresponds to 10500 AVI. All in all 323 AVI is the estimated total number for the city of Fes. Since, there is no consensus on the monetary valuation of the AVI, the human capital approach, through which the economic value of a year lost due to illness is equivalent to PIB per capita (Croitoru & Sarraf 2017). For the city of Fez the PIB per capita is 20498 MAD. As a result, the cost of adult morbidity due to diarrheal diseases is 6.62 million dirhams. That is 0.0153% of the VA.

***The quality of life*:** To calculate the losses of the quality of life of the population it is essential to use the method of the availability to pay DAP. For that we adopt the values of the study of mesotourism of Morocco where the DAP for the inconvenience because of a patient is 20 MAD (Maradan & Zein 2008b) and the DAP for a better life related to the quality of the waters is 528 MAD (Maradan & Zein 2008b). Thus, the total annual cost of the loss of quality of life is estimated at 22.29 million dirhams. That is 0.051% of the VA.

Natural capital: While it is true that the city of Fez has made remarkable progress in the field of water resources through the construction of the wastewater treatment plant, there are still problems that have serious negative impacts on the capital. Natural in fact, untreated wastewater, infiltration of leachates generated by waste from temporary depots or overflows from the controlled landfill, plus the opportunity cost which remains very low. All these parameters affect both the availability of water and its quality.

***Costs related to decreasing the quantity of resources*:** The annual cost of exploiting the natural resource was estimated on the basis of the opportunity cost; for the city of Fez the annual volume withdrawn from nature is 75816352 m^3 according to ONEP and RADEEF and the cost opportunity is of the order of 0.4 MAD /m^3 according to ABHS, so that the annual cost linked to the decrease in the quantity of resources is 30.32 million. That is 0.07% of the VA.

Costs of degradation of the quality of water resources: To estimate the cost of degradation due to not only the discharge of untreated wastewater but also leachates infiltrated into the ground, is based on the cost of treatment of contaminated water 10 MAD/m^3 according to data from the Ministry of the Environment. Several studies have shown that 1 m^3 of wastewater pollutes about 50 m^3 of water. The same hypothesis has been adopted in the case of leachates, hence the quantity of polluted water is approximately 46249732 m^3. So the cost generated is of the order of 462.50 million dirhams; that is 1.066% of the VA.

Inefficiencies: Inefficiencies in the use of water resources have been retained from three angles: losses during transport, losses during distribution and finally inefficiencies when used by various factors (households, industries, crafts, tourism, etc.).

The losses represent almost a quarter (20%). According to the RADEEF, the water loss index at the time of distribution is 32.77 m^3/d/km.

We rely on expert advice to determine inefficiencies when using, households 10%, industry and crafts 30%, administration 30%, tourism 40%.

The annual cost of all these losses has been estimated on the basis of the selling price of water by the RADDEF, 230.04 million dirhams; that is 0.53% of the VA (Table 1).

Remediation Costs (CR)

Remediation actions should have results in the least cost elimination of damage and inefficiencies.

With regard to water, remediation costs include treatment of untreated wastewater and connection of non-connected households for the health and quality of life category, and of course, the reduction of losses at all levels for inefficiency category. As for the natural capital category and to avoid double counting, we put in the tables a value of 0; indeed the remediation of the depletion of resources already counted under "inefficiency". While the quality of the resource is counted under "health and quality of life".

The cost of remediation of the wastewater discharged is estimated using the cost of treating the raw wastewater at 30 MAD/m^3 (Croitoru & Sarraf 2017). For the community studied, the total volume of raw wastewater equals to 916625 m^3. The cost of remediation is 27.50 million dirhams. That is 0.063% of the VA.

The cost necessary to connect 10601.44 households to sanitation and drinking water is 6.9 million dirhams. It is based on the average cost of connection, that is 0.16% of the VA.

The reduction of losses by 2/3 and the investments necessary to achieve this objective would cost 571.87 million dirhams, that is 1.319% of the VA (Table 2).

CDI/CR Ratio: Net Remediation Benefit

The ratio CDI/CR = 1.49 [CDI (2.087)/CR (1.398)] shows that the CDI due to the deterioration of the water resources of the city of Fez are much higher than the CR. Indeed, the investments to be made to reduce the impacts caused by the

Table 1: Value of the costs of damage and inefficiency (CDI) by economic category.

Economic categories	% of the VA
Health/Quality of Life	0.421
Natural Capital	1.136
Inefficiencies in resources	0.530
Total Water	2.087

Table 2: Remediation costs (CR) by economic category.

Economic categories	% of the VA
Health/Quality of Life	0.079
Natural Capital	0
Inefficiencies in resources	1.319
Total	1.398

pollution of the water resources remain financially significantly lower compared to the CDI.

DISCUSSION AND CONCLUSIONS

The study shows that the cost of water degradation and inefficiencies in the use of this precious wealth is estimated at 905.26 million dirhams, that is 2.087% of the added value (VA) of this municipality. The deterioration of the health and the quality of life contributes by 0.421% of the VA, the degradation of the natural capital is evaluated to 1.136% of the VA and the inefficiencies in the use of the resource contributes by 0.530% of the VA. The remedial actions show that the category health and quality of life is placed as priority area of intervention (CDI/CR = 5.32).

Despite the remarkable progress of the city of Fez in the field of environmental protection, specifically water resources, this study has highlighted, in numerical terms, persistent shortcomings in the field of the protection of this environment resource. These shortcomings are likely to become more important in the coming years if we take into account the significant development experienced by the city, the demographic pressure to which is added the vagaries of climate. This study allows decision-makers to better understand the gaps in resource protection and to better target the priority areas of their actions.

Finally, it will be recalled that this analysis applied to the seven environmental domains: water, air, noise, soil/landscape, waste, energy/material and the global environment will enable us to identify and prioritize action priorities as an integrated approach to the protection of environment and strengthening the well-being of the people of this millennial city of the kingdom.

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LIST OF ABBREVIATIONS

AVI: Year of Life lived with Incapacity
ABHS: Sebou Hydraulic Basin Agency
A/C: Benefits / Costs Report
CDI: Damage and Inefficiency Costs
CR: Remediation Costs
DAP: Availability To Pay
DALY: Dirsability Adjusted Life Years (life year corrected for disability factor)
ENPSF: National Population and Family Health Survey
Ha: Hectare
MAD: Moroccan Dirham
WHO: World Health Organization
ONEP: National Office of Drinking Water
GDP: Gross Domestic Product
RADEEF: Autonomous Board of Distribution of Water and Electricity of Fez
T: Tons
VA: Added Value
VSV: The Statistical Value of Life