Inter-sectoral competition for water allocation in rural South Africa: Analysing a case study through a standard environmental economics approach

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Abstract

South Africa has adopted an ambitious new water legislation that promotes equity, sustainability, representativity and economic performance through water management decentralization, new local and regional management institutions, water users' licensing, and the possible emergence of water rights' markets.
This paper addresses the diversity of water users and uses that currently exists in rural areas, and especially focuses on the competition for water that may result from such a diversity in a context of water scarcity, and from the diversity of objectives formulated by the public authorities. The paper first briefly describes the current institutional arrangements regarding access to water. It also presents the situation in rural areas where farming communities and the mining sector are interacting on water- and labour-related matters. The paper then presents a case study whereby these two sectors have embarked into a negotiation process on water rights transfer, under the auspices of several public role players. It proposes an analysis of the case study through a standard environmental economics model. The model considers the marginal net private benefit (MNPB) generated by mining activities and the associated marginal returns to water (MRW). The transfer of water from farmers to mines results in a loss in crop production potential by the farmers and the subsequent loss of income and potential for development. Such a loss can be considered the opportunity cost of water for smallholders. If not compensated, it represents a proxy of the externality associated with the water transfer. The model first highlights the difference in terms of water productivity in the two sectors, and its consequences if a system of transferable licenses is adopted. Then, some policy options (taxes, standards, subsidies) are tested and discussed.

1. Introduction

The National Water Act (1998) of South Africa is internationally recognized as a most promising legal framework to adequately address the countries' challenges in water management (Hamann & O'Riordan, 2000; Perret, 2002). However, the Act promotes several objectives (i.e. resource protection, social equity and development, economic efficiency) that may seem contradictory in a context of resource scarcity, severe backlogs in rural areas, competing users, needs for economic performance and job creation in rural areas, and so on. This creates a strong dilemma, which is weighing onto the water allocation processes. Perret (2002) described and discussed the institutional context and the possible implications of the new legislation on rural settings and especially small-scale irrigation users. This paper proposes a standard environmental economics perspective to the issue.
The paper presents a specific case study in the Olifants River basin, where mines try to extend their water rights (quota allocation) at the expense of small-scale developing farmers (Arabie-Olifants irrigation scheme). It first describes the specific roles that mining and agricultural activities play in rural areas, and the situation regarding the water resource. The paper then briefly presents some key traits of the new water legislation. It proposes a standard environmental economics model on externalities' bargaining to analyse the rising inter-sectoral competition for water rights between the mining sector and small-scale developing farmers. Finally the paper explores policy options for regulating such inter-sectoral competition, or for promoting any given orientation (e.g. equity, local rural development, economic performance and job creation, etc.).

1.1. Agriculture and mining as interacting productive primary sectors in rural South Africa

South Africa is a lower middle-income country characterized by a two-faceted primary economic sector, with agriculture and mining. Agriculture accounts for a particularly low share of GDP compared to most other countries of its category. Although it has a well-performing commercial sector, agriculture represents about 3.5 percent of GDP and employs 9 percent of the total active population. Moreover, irrigated agriculture and stock watering use about 52 percent of total water. Mining activities account for about 7 percent of GDP and use about 3% of total water usage. It employs about 6% of the total active population. (Government Communications and Information Systems-GCIS, 1998; Forgey et al., 1999).

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However, these figures do not reflect the actual impact of those two primary activities in rural areas' livelihood systems. Although not declared as formal employment and not generating much cash income, farming activities form the backbone of most rural activity systems in the former homeland areas [3], especially for the poorest and women-headed households (Barber, 1996; Perret, 2001). Kirsten (1996) highlighted "the lack of diversity in the rural non-farm economy and a virtual absence of small-scale industries and other value-adding activities". A major part of rural income is generated through claims, grants, and remittances by migrants. More than 50% of rural households use exclusively unpaid family members as farming labour force. 92.6% of them farm only to produce enough food for the household to eat (Forgey at al., 1999). More specifically, community gardens and smallholding irrigation schemes play key functions on subsistence and food security at community level. Water is the most needed input, as expressed by rural households (Forgey et al., 1999).

Mining and quarrying activities, on the other hand, often offer the only significant formal male employment opportunity in deep rural areas, despite current re-structuring plans leading to lay-offs. The sector employs up to 17% of the employed active population in rural provinces, and provides more than 50% of all formal jobs at certain local rural settings (e.g. in the North West province) (Forgey et al., 1999). Mining provides higher paying opportunities than farming for rural black labour force (Low, 1986). This off-farm market dominates labour allocations and generates adult male migration. Therefore, workers who remain on the farms are those with the lowest opportunity costs as defined by the external labour market, which favours men. Thus, many rural households are *de facto* headed by women or pensioners for whom household and child rearing responsibilities exclude them from intensive field labour in agriculture (Perret, 2001). Such is the case in community irrigation schemes for instance (Shah & Van Koppen, 1999; Merle et al., 2000).

The two primary sectors are also increasingly competing for natural resources, and especially water. South Africa is a water scarce country, due to its low average annual precipitation (less than 500mm), and the unevenness of surface and groundwater distribution that results from climate and geography (21 percent of the country receives less than 200mm). Davies & Day (1998) estimate that there will be no spare water in South Africa beyond 2020 if the whole population is adequately supplied. For the basin that includes the case study area (Olifants River basin, see map 1), there will be no water available for further allocation by 2010.

1.2. A new water legislation and policy

With the dismantlement of former regulations and the adoption of a new democratic constitution, South Africa also adopted a new water policy, represented in the new National Water Act (RSA-NWA, Act 36 of 1998). The new act broke drastically with the previous water laws. Water is now considered a common asset. The right to use water is granted to users, most of whom have to be registered and licensed, and should pay for this right. Also, the core concept of water management under the new dispensation is decentralization. Finally, protective measures are meant to secure water allocation for basic human needs, ecological and development purposes (the concept of Reserve).

Social development, economic growth, ecological integrity and equal access to water remain key objectives of the new water resource management regulation. New management entities (Catchment Management Agencies and Water Users' Associations) will be established in order to achieve the aims of the Act. These institutions are currently established at regional and local level, respectively, emphasizing a largely decentralized and participatory approach to water resource management. The process however shows slow and uneven through out the country. Furthermore, past water rights often still apply since the implementation of the new water legislation is still under way.

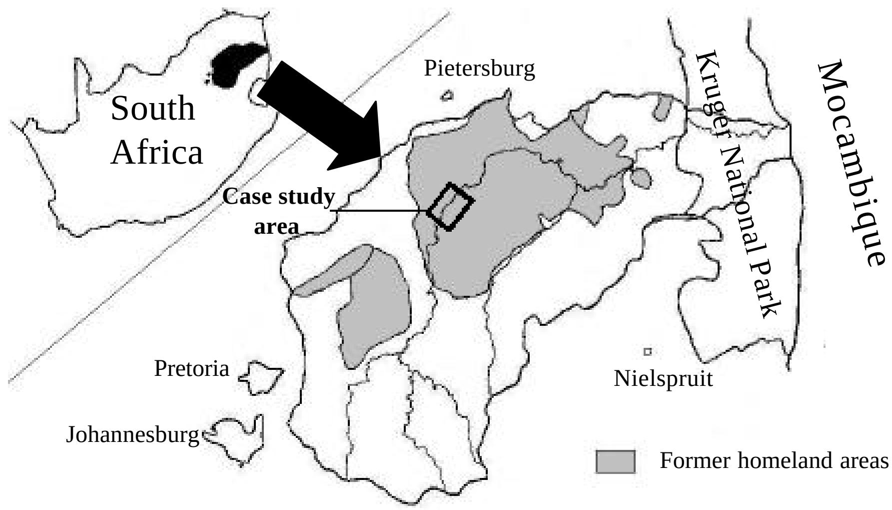
1.3. A legal and economic background for inter-sectoral transfers of water rights

It has been argued by a number of authors (Armitage, 1999; Louw and Van Schalkwyk, 2000) that the new Water Act provides the framework for water markets in South Africa. Although stated vaguely the water legislation makes provision for water rights trading as an option for water allocation (the legal transfer of water use licenses) (Perret, 2002). Under the past legislation, sectorial water-rights trading occurred and still exists between commercial irrigation farmers (Armitage et al., 1999) and has proved efficient in certain instances. It

[3] From the Natives Land Act of 1913 on, a number of homeland areas (also derogatorily called Native areas) were delineated according to ethnic, geographical and economic criteria, and formed "reserves" for black people. Such spatial discrimination was developed and implemented further under the apartheid regime from the 1950's on. Reserves were granted some form of autonomy from central government. Some of them ultimately were declared self-governing independent states (Bantustans), although not recognized internationally. Homelands and the so-called independent Bantustans have all been re-incorporated into the country in 1994 (see map 1 with examples in the Olifants river basin)

must be emphasized that the Department of Water Affairs and Forestry (DWAF) played an important role in the successful cases, assuring transparency, supervising and recording transactions.
New mines' settlements and growing water needs form the ground for inter-sectoral transfers. Some settling mines are just investigating the possibility of buying water rights from small-scale irrigation schemes (SIS) (Development Planning & Research, 2000), while others are already proactive and have embarked onto negotiations with communities and/or local, provincial and national authorities (Rouzère, 2001).

Map 1. The Olifants River basin: the former homeland areas, and the case study area (Perret, 2002)



2. Materials and methods

The following chapters refer to negotiations that have already taken place in an area of Limpopo (former Northern Province) in the water-stressed basin of the Olifants river (see map 1), under close monitoring by DWAF and the Limpopo provincial Department of Agriculture and Environment (L-DAE). The idea behind it is that most SIS are not currently using their entire water rights, in terms of allocated quantity, while newly settled mines or mines expanding their activities are in dire need of water. In the case study, the key stakeholders of the negotiation are the mines, the provincial authorities (L-DAE) and DWAF, and the smallholding farmers of the Arabie-Olifants irrigation scheme. Primary data and information were collected during a survey (Rouzère, 2001), complemented with existing secondary data (DWAF, 2000; BKS, 2001).

2.1. Competition for water between mines and developing farmers

In the Middle Olifants region, one of the poorest in the country, new mines intend to settle and others wish to develop and set up new plants. The sector's need for water is growing accordingly. The available water of the sub-basin, mostly stored upstream the Arabie dam, is already totally allocated (56 million m^3 per annum). Furthermore, secondary dams are silting up and water stocks are subsequently decreasing.
In order to increase the resource availability, technical and institutional options have been envisaged. From a technical point of view, DWAF proposes to either heighten the Arabie dam by 5 meters, or build another dam (further downstream, at Rooipoort). From an institutional point of view, it has been envisaged to re-allocate existing water rights, and to delay the application of the Reserve (portion of the resource kept un-available for allocation, and dedicated to basic ecological and human needs purposes) until new water-works and resource development.
A smallholding irrigation scheme (Arabie-Olifants I.S.), operated by black communities, lies downstream the Arabie dam. It covers 2818 irrigable hectares. 1650 smallholders' households partake in the scheme, mostly for food supply and subsistence purposes. This represents about 13000 people. Plot sizes range from 0.5 to 5 ha. According to previous allocation arrangements, the scheme was allocated 18 million m^3 per annum, which represents about a third of the resource available at sub basin level. However, it is estimated (Rouzère, 2001) that farmers currently use less than 30% of this quota (which means that just about 500 ha are probably properly irrigated nowadays). Such situation owes to extensive and subsistence-based cropping systems, followed by the

majority of non-farming plot occupiers, and to obsolete and deteriorated irrigation infrastructures. It has been estimated that full rehabilitation of the scheme's infrastructures would cost 30 million South African Rand[4] (BKS, 2001).

In 1999, some mining companies applied for extended water allocations to DWAF for establishing new plants in the area. At the beginning of 2001, in view of the increasing and pressing demand by the mines and the lack of further allocable water, DWAF suggested to temporarily re-allocate to mines some water rights currently held by farmers (13 of the 18 million m^3 per year). Negotiations took place between representatives of the mining sector, DWAF and the L-DAE, the latter acting as a representative of smallholders and communities. It was agreed that the mining sector would pay a compensation of 7 million Rand, allocated to the partial rehabilitation of the irrigation infrastructures. This amount represents less than 0.1% of the total cost of the mining development scheme. Such an arrangement is supposed to allow the mines to operate quickly, according to their plans and to give DWAF more time to make further plans regarding resource mobilization in the area (upgrading/heightening the existing Arabie dam, building a new one).

As a decision-making support, DWAF built a model on water availability (56 million m^3/year) versus demands in the area, taking into account the consumption dynamics from 2000 to 2020 for the major sectors: basic human and ecological needs (Reserve), domestic water, transfer to Pietersburg (main neighbouring urban centre), irrigation and mining. Table 1 sums up the outcomes of a scenario-testing approach with such a model.

Scenario 1 is the *status-quo* scenario. Scenarios 2 and 3 can be seen as balanced scenarios, since they accommodate the mines' requirements while protecting other users. Scenario 4 favours mines and still protects farmers, but infringes on the reserve. Scenario 5 favours mines and protects the ecological reserve, while leaving farmers with a stagnant quota. Scenario 6 clearly favours mining development to the detriment of other users.

Table 1. Scenarios on resource development needs, according to different management options (present secured water: 56 million m^3/year)

Scenarios:	***1***	***2***	***3***	***4***	***5***	***6***
Allowing partial mining development	No	Yes	Yes	Yes	Yes	Yes
Allowing for complete mining development	No	No	Yes	No	No	Yes
Water re-allocation from irrigation to mines	No	Yes	Yes	Yes	Yes	Yes
Limited ecological reserve until 2009	No	No	No	Yes	No	Yes
Limited irrigation development until 2009	No	No	No	No	Yes	Yes
Need for heightening the existing dam (Arabie)	**2010**	**2005**	**2004**	**-**	**-**	**-**
Need for building a new dam (Rooipoort)	**-**	**2009**	**2007**	**2009**	**2008**	**2009**

Source: Rouzère (2001) quoting DWAF.

It must be noticed that:

- All alternative scenarios envisage water re-allocation from farmers to mines, although most with a progressively increasing quota for farmers (2, 3 and 4, allowing for development);
- Some alternatives investigate quota-freezing or -reduction options for farmers and/or the ecological reserve (4, 5 and 6);
- As a whole, these scenarios aim at two objectives: accommodating new mines' settlements and giving DWAF some time to implement new resource developments;
- By 2020, the sub basin should be closed in term of water availability anyway (i.e. regardless of new water resource development whatsoever), meaning that all users will compete; from the above, it is clear that smallholding irrigation farmers will be the targets of water re-allocation, as the unique possible resource.

Such situation forms the background of the present paper. A standard environmental economics model is developed and represents the competing demands for water from the mining sector and the smallholding irrigation sector.

2.2. The model: mines' returns to water vs. farmers' opportunity cost of water

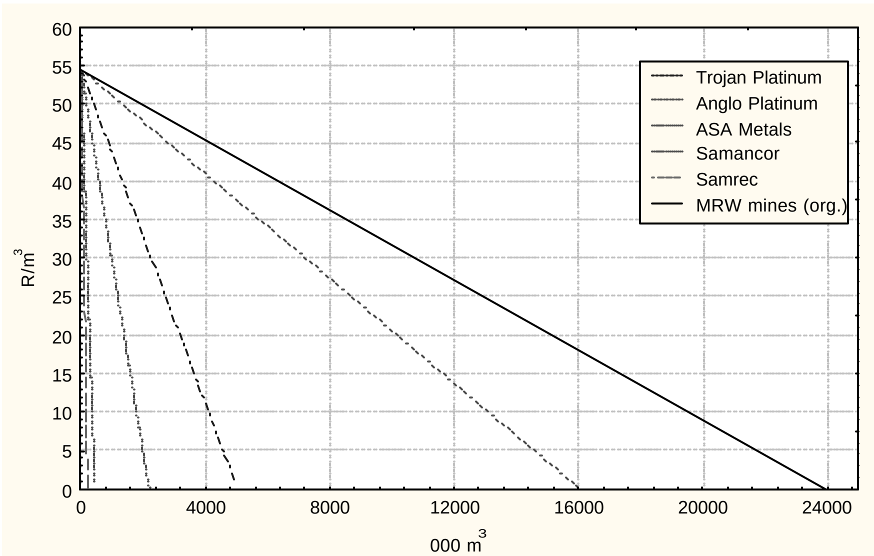
Mines are considered the potential beneficiaries of water rights transferred from the small-scale irrigation sector. The ideal and correct way of presenting the comparative analysis and tradeoffs is to use marginal values. That means comparing mines' Marginal Returns to Water (MRW) with the Marginal Opportunity Cost (MOC) that results from the non-use of water by the smallholders (considered here a negative externality). However, lack of data precluded derivations of marginal values and this study could only estimate average returns and costs. These are used as proxies to marginal values to conduct the analysis.

Five new mining sites (see figure 1) will be developed in the area. Their aggregated water demand is deemed to reach approximately 24 million m^3/year by 2020. The annual benefit of Anglo Platinum (the biggest mining

[4] Exchange rate: 1 US$ makes about 10 South African Rand (mid 2002)

group in South Africa) is R 1.75 billion per mining site[5]. One of the five new sites will be theirs. It is assumed that all sites will have the same water productivity, meaning an even MRW per unit of water used (supposed to be 25% of the marginal benefit). Finally, it is assumed that the MRW curve is linear[6] (as well as the Marginal Net Private Benefit curve in: Pearce & Turner, 1990; Baumol & Oates, 1988) and that the different mining companies co-ordinate their water demand (aggregation of MRW). The sector's MRW by 2020 is represented in figure 1, as well as the MRW curves of each mining site[7]. At this stage we consider that mines have no possibility to save on water through technical innovation. Therefore, the only way to save on water is to reduce production. Technical innovation will be c onsidered later on.

Figure 1. Marginal Returns to Water vs. water consumption within the mining sector (in a sector co-ordination scenario)



The mining sector MRW curve in the case study area has the following function[8], according to the above-mentioned assumptions:

$y = -0.00228x + 54.48$

where:
y= mines' sector Marginal Returns to Water (in R/m^3water)
x= water used (in 000 m^3)

Integrating that function for 0<x<23.944 provides the Returns to Water (RW) of the mining sector in the area:

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[5] Calculated as follows: 7 billion R is the benefit realised by the group Anglo-Platinum in 2000 (Rouzère, 2001). Four Anglo-Platinum mining sites are at present operating in South Africa and they have approximately the same size. The new site foreseen in the studied area will also have the same size. Therefore, annual benefit as R 1.75 billion has been estimated. The poor availability of figures in this economic sector requires on the one hand making many assumptions and on the other hand investigating on the nature of these data. Particularly, a crucial point for future analysis is to clarify the nature of the "benefits" indicated by the available sources. In fact the results of our model may change radically if these "benefits" are "pure profits" (margins after having subtracted from the gross income returns to capital, resources, labour, and input costs), or "gross margins", and in this case it would be important to understand what returns are still included within the so-called "benefits". In the model it is assumed that the residual returns to water is 25% of the "benefits" for both the mining sector and smallholders.

[6] The same assumption is made for MOC as well.

[7] Another way to estimate the water value for different users is to build production functions where water is one of the production inputs. These functions are econometrically derived from available data.

[8] For the estimation of the MRW function, assuming the values of MRW at x=0 =[(NPB/water consumption*2)*0.25] and at x=23.944 million m^3 (MRW=0), a line can be traced, which links up these points and corresponds to the MRW function.

The same method has been used for calculating MOC of water for smallholders.

$$RW = \int_{0}^{23944} (-0.00228x + 54.48)\ \partial x$$

At present, 18 million m^3 of water are allocated to smallholding irrigation farmers downstream the Arabie dam. About five million are actually used for irrigation. Considering the productivity of irrigation water for different crops and the existing farming systems, it has been chosen to put forward two types of scenarios in terms of scheme's orientation. On the one hand, a subsistence-based scenario actually reflects the current situation whereby farmers are valuing irrigation water mostly through maize production for self-consumption (benefits = 0.57 R per m^3). On the other hand, a commercial orientation scenario suggests that increased use of inputs by farmers, training and secured access to markets and to water (especially in winter) would increase land productivity and net income, generate crop diversification, and water productivity (benefits = 1.98 R per m^3). Although simplistic, these scenarios reflect the options and challenges facing the farmers in the Arabie-Olifants scheme. As for the mining sector, returns to water have been considered as 25% of the calculated benefits for the two types of smallholders (table 2).

Table 2. Returns to water at farming system levels in the case study area (drawn from Perret & Touchain, 2002; Merle et al, 2000; Small & Stimie, 2000)

Farming systems	Returns to water per m3 of irrigation water used
Subsistence-based farming systems, with casual marketing (low yielding summer maize, no winter crops)	0.14 R per m^3
Commercially oriented farming system (average yielding summer maize, mostly sold, vegetable crops grown in winter)	0.50 R per m^3

This allows an evaluation of the opportunity costs resulting from a transfer of water from farmers to the mining sector. Such costs are considered the loss of private benefits resulting from the "non-use" of water by irrigation farmers[9]. Such non-use of water refers to dry land cropping, which, in the semi-arid case study area, is impossible in winter (vegetable crops), and leads to high risks of maize cropping failure in summer. Such situation allows for the assumption that dryland cropping does not generate any net income (farmers faced with frequent water shortage usually eventually relinquish crop farming).

Because negotiations between smallholders and mines call for a re-habilitation of the scheme by 2015, the opportunity cost has to be applied to the whole amount of water allocated to farmers, although they use only 30% of it. According to table 2, a commercially oriented scheme generates the best returns to water (0.5 R per m^3), which is one scenario proposed here. The second scenario, more realistic with respect to the current situation, suggests a subsistence-based scheme, which values returns to water at 0.14 R per m^3. Smallholders' water Marginal Opportunity Cost (MOC) is calculated making the same assumptions as for the mining sector's MRW.

Assuming that the MOC curve is linear, the two scenarios regarding the scheme's orientation have the following functions:

$y = 0.0000555\, x$ for the commercial scenario

$y = 0.0000155x$ for the subsistence scenario

where:
y= smallholders' MOC for water (in R per m^3)
x= water used (in 000 m^3)

[9] With regard to the negative as well as the positive *externalities* incurred with the transfer of water from agriculture to the mining sector, the calculated opportunity cost of water for smallholders under-estimates them, because it does not consider important social effects (e.g. unemployment) and environmental effects (e.g. loss of fertility in abandoned land). On the other hand, it is even higher than the farmers' perception of the external cost. The latter is for them identifiable with the gross productivity (not considering returns to labour, capital and resources) of water in the area, which is often not higher than the 1.6 cents/m^3 corresponding to non irrigated crops.

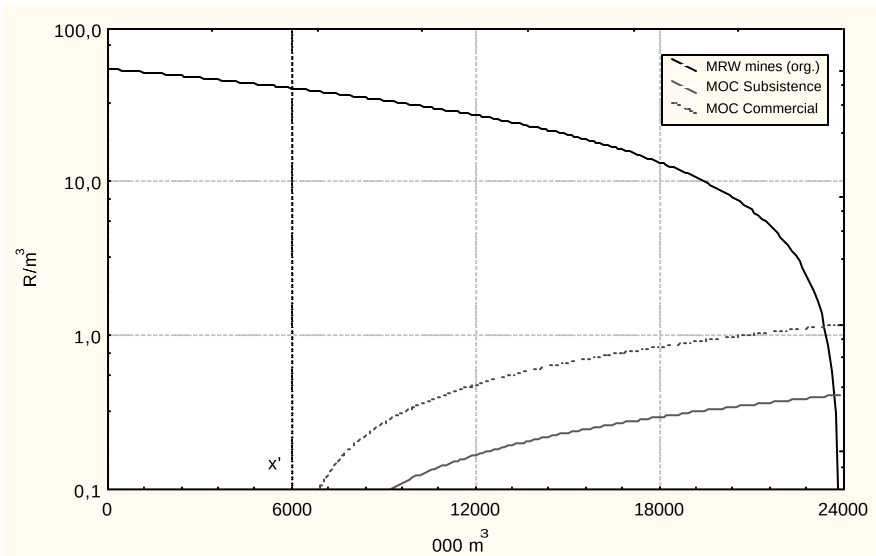
These MOC curves are shown in figure 2 (using logarithmic scale in y axis, for clarity purpose), where they are confronted with mines' MRW. The hypothesis is that up to x' (6 million m^3/year), mines' water demand is satisfied at the expense of the Reserve[10] or, in any case, not intaking the 18 million m^3/year allocated to smallholders. Therefore, up to x', there is no MOC of water for smallholders.

The MOC curves in this figure have the following functions:

$y = 0.0000555\,x - 0.333$ for the commercial scenario

$y = 0.0000155x - 0.093$ for the subsistence scenario[11]

Figure 2. Mining sector's MRW and farmers' water MOC vs. water consumption by the mining sector (logarithmic scale in y axis, for clarity purpose)



3. Discussion: setting up policy tools

The model lies on empirical data collected on a case study. In spite of a number of assumptions and uncertainties about the figures that weaken its genericity, such model proves interesting for investigation and demonstration purposes. The model clearly reveals the difference in economic power between the two sectors. This means that a direct negotiation (in the sense of Coase, 1960) on water rights transfer between mines and smallholders is likely to end up with an almost complete transfer of water rights to the mining sector. This would certainly have positive consequences in terms of strict economic efficiency, water productivity, and even formal employment in the area. On the other hand, such a transfer would challenge certain objectives of the government, which go beyond mere economic perspectives and include equity, sustainable rural development, environment protection, and the like. Certain economic or regulatory policy tools may be implemented, as alternatives towards a more balanced allocation of water.

In order to simplify the presentation, the volumes of water introduced above will be approximated as follows: mining sector needs =24 million m^3/year; present allocation to smallholders = 18 million m^3/year; water at present really used by smallholders = 5 million m^3/year; water belonging to the Reserve = 6 million m^3/year.

[10] For a definition of the Reserve, see 2.1.

[11] If water MOC for smallholders is related to the present use of water (30% of the total allocation = 5.4 million m^3/year), the MOC function is:

$y = 0.0000555\,x - 1.032$ for the commercial scenario

$y = 0.0000155x - 0.2883$ for the subsistence scenario.

3.1. Definition of a norm (or standard)

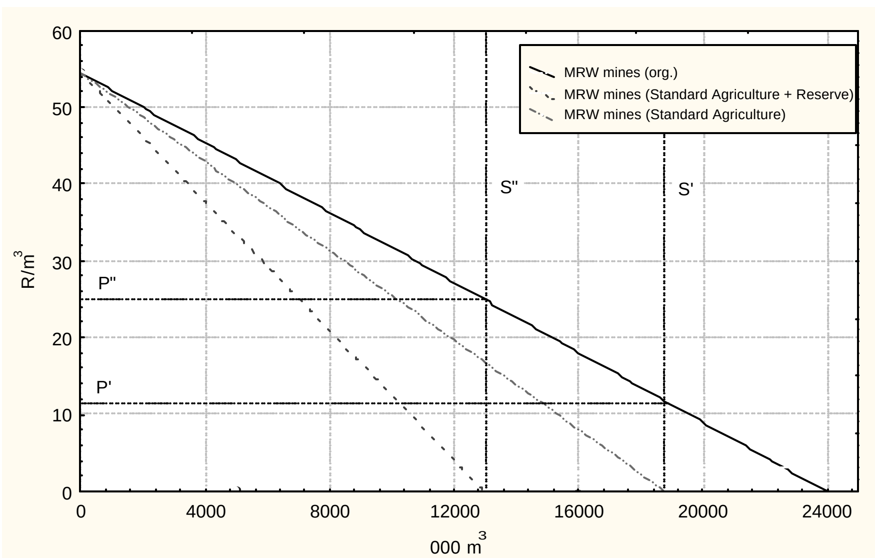
A first option may be the definition of a norm or standard, in the form of a reserved quota for irrigation. Such an option is one of the key features of the scenarios that DWAF envisages in the case study (see table 1, with application to smallholding irrigation and/or the ecological reserve). Figure 3 shows how this option preserves 5 million m^3 for small-scale irrigation use, and alters the mining sector's MRW. A penalty (P') should be combined with the definition of the norm. Such a penalty corresponds to the MRW of the mining sector (as shown in figure 1), but at the level of the norm (19 million m^3, the penalty being set at about R11 per m^3). No double dividend is generated with such a tool.
A new function defines the MRWs' of mines respecting the standard (19 million m^3):

$y = -0.0029x + 54.48$

If the government wants to preserve the Reserve along with the quota effectively used by the smallholders, the standard will be set at S", the related penalty being P" (i.e. 25 R/m^3), and the new function defining MRWs" being:

$y = -0.0042x + 54.48$

Figure 3. Using standards for preserving smallholders' quotas and the Reserve

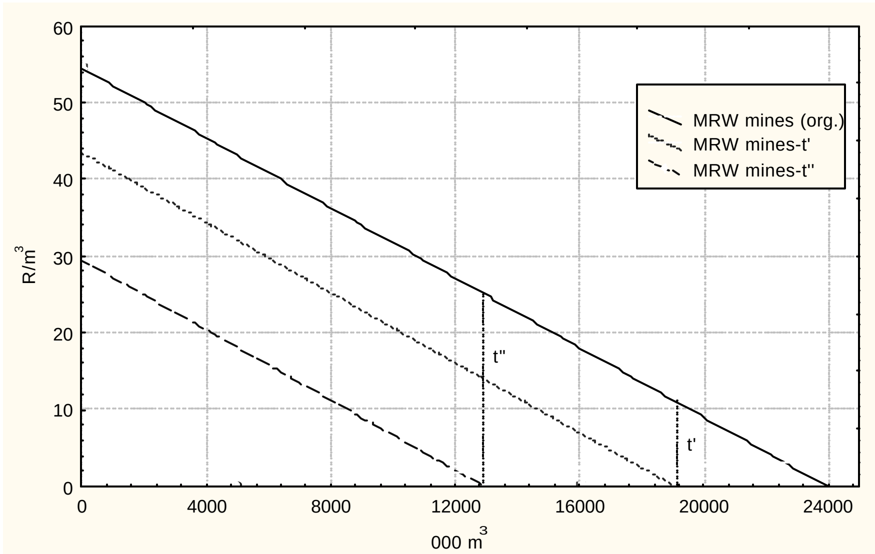


3.2. Water use tax

A second option may be to levy a tax from the mines for using water acquired from a transfer. Figure 4 shows that a tax of 11 R per m^3 used (t') would set the mines' MRW to zero at a water consumption of 19 million m^3. Hence the likely preservation of a 5 million m^3 quota for irrigation farmers. This would also generate a water management revenue (double dividend), which might be used for several purposes, e.g. rehabilitation of irrigation schemes, unemployment and welfare grants, inciting measures and aids to mines for water saving and recycling, and so on.

Similarly, a tax of 25 R per m^3 (t") could set mines' MRW to zero at a water consumption of 13 million m^3, which would preserve the Reserve quota and therefore match the environmental objective in addition to the equity one.

Figure 4. Taxation of mining water use: downsizing the mining sector's MRW and securing quotas for irrigation and the Reserve



3.3. Bounded water rights market

The National Water Act explicitly mentions the possibility to exchange and trade water rights, allowing for establishment intra- and inter-sectoral water-rights markets. The base model (figure 2) reflects a free market situation whereby there is no limitation to water right transfers amongst sectors or users, and the Reserve is first allocated to mines. In such a case, establishing a negotiation between mines and smallholders for a 18 million m^3/year initially allocated to smallholders would draw the system to a quasi-complete transfer of these quotas to the mining sector. Even in the most optimistic scenario of commercial farming, less than one million m^3 would stay in the agricultural sector.

If the Reserve is not previously allocated to the mining sector, then mines and smallholders will compete not from x_0=6000, but from x_0=0; in other word, the MOC will be positive from x_0=0. This case is illustrated in figure 5, which shows that: i) leaving complete freedom to market forces would quickly transfer all the water allocated to smallholders to mines; and ii) setting a limit (quota) preserving agriculture (5 million m^3/year) and the Reserve (6 million m^3/year), in other words bounding the water rights market within the 13 million m^3/year currently unused by the agricultural sector is an unrealistic and cost-uneffective solution. The huge gap between the price of one cubic meter of water corresponding to a mines' consumption of 13 million m^3/year, respectively for the mining sector (Pm), and for smallholding irrigation (in the two scenarios envisaged: PSc for commercial and PSs for subsistence) does not allow for a realistic application of an inter-sectoral bounded water-rights market. If one wants to reach the same result (i.e. the application of the "user pays" principle), a tax applied to the wealthier sector appears to be a more suitable instrument.

3.4. Incentives for water-saving technologies and innovation

Finally, the mining sector has already announced its willingness to introduce water-saving technologies, enabling it to reduce water consumption up to 4 times by 2020. Every sector and water management at large in the area would benefit from such a strategy, since it would sustain the mines' level of productivity while preserving the resource and other users. Overall, externalities and negative impacts on other sectors' allocation would be reduced (Ayres, 2000). Unfortunately, in the case of the Arabie area, such improvement would just delay the competition for water and the need for extended resource. DWAF reckons that the area would face water resource closure by 2020 anyway. An inter-sectoral competition, and possible conflicts, are therefore inevitable.

Figure 6 illustrates the changes in mines' MRW resulting from a 100% water saving through innovation and technology change.

Figure 5. Water-use tradable permits with a limit to 13 million m^3/year

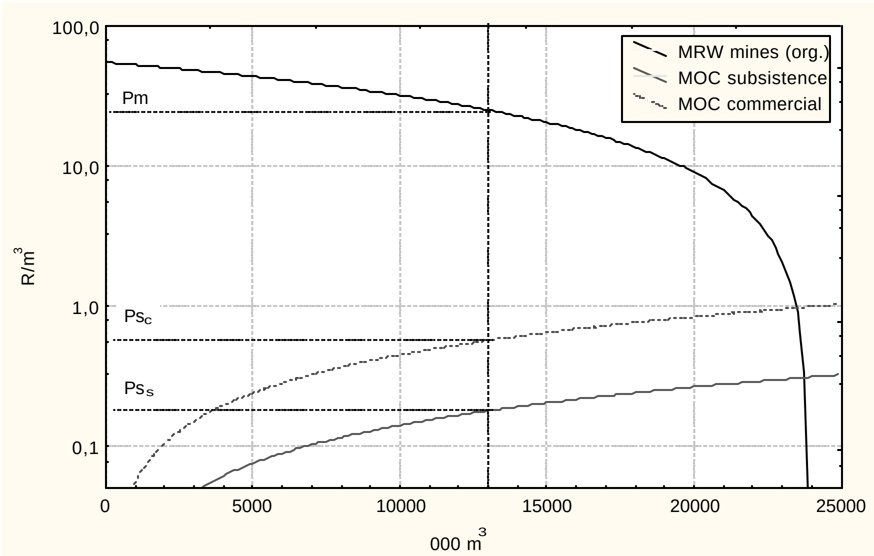
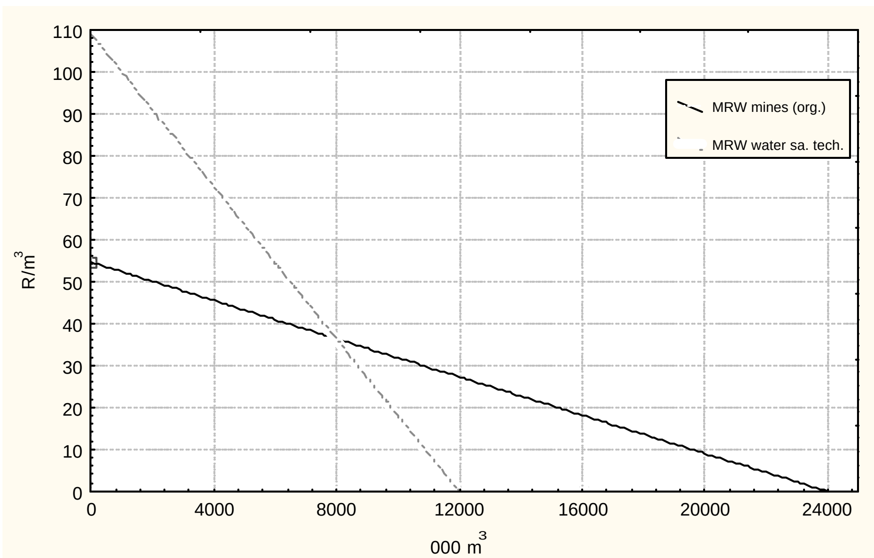


Figure 6 . MRW mines at present, and with a 100% water saving through innovation and technology change



4. Conclusions

The productivity of water in the mining sector is far higher than the one of smallholders' irrigation. Such a gap allows for the mining sector to offer prices for water rights (licences) ten to twenty times higher than the smallholders (in case of a water rights market being established). If a free water-right market were really implemented, such unbalanced willingness to pay would result in the total transfer of water rights allocated to the smallholding irrigation sector towards the mining sector (18 million m^3 per year). The latter will need more water anyway, in order to satisfy its needs. Further water (about 6 million m^3) would then be taken from the ecological reserve, or through resource development (a new dam).

As reported by Romano (2001), such a process occurred in Chile during the last 20 years, after the implementation of a liberal water legislation that established a free water-rights market (public authorities just recorded the transactions but did not intervene in any manner whatsoever in their contents). Smallholders progressively sold their rights to other users, resulting into decreasing agricultural production, then further rural poverty.

If a certain amount of water is to be reserved for the smallholding agricultural sector (e.g. the 5 million m^3 per year currently used), for equity and rural development concerns for instance, an intervention by the public authorities is necessary. The model allows for testing some water-management policy tools. Some may show effective and useful with regard to the above-mentioned concerns.

The simple definition of a norm, in the form of a quota of water compulsorily reserved for agricultural use (command and control approach), raises the problem as to how to control the system, enforce it, and deal with possible transgressions. The model allows for the calculation of the effective penalty to be imposed to transgressors. This approach, besides the issues and costs related to control and enforcement, does not create any double dividend. It leaves mines with a higher benefit for the same amount of water allocated, which is not the case when considering a tax (see below). Finally, such a system refers to the "compulsory licensing" one that DWAF plans to implement in resource constrained basins (DWAF allocates non-transferrable quotas to the different users, regardless of their specific demand).

The adoption of a tax per m^3 of water used by the mining sector is another option (as an economic instrument). The model shows that, in order to sustain the current quota used by smallholding agriculture, a 11R/m^3 tax should be levied from the mining sector. This tax would rise up to 25R/m^3 if the Reserve quota has to be preserved. Although theoretically possible and relevant, such a levy may prove difficult to justify and to implement. This type of measure would drastically reduce the private benefit of mines and would create a double dividend (in the form of an income to the water management entity), which might be used within the sector (e.g. through incentives for those mines willing to invest in water-saving technologies), or outside the sector (e.g. for general water management purposes).

The hypothesis of allocating 18 million m^3 per year to the smallholding irrigation sector, and the subsequent establishment of a water-rights market limited to 13 million m^3 per year, does not seem realistic. The gap in the willingness to pay water between the two sectors is too large and would lead to a quick and total transfer of licences to the mining sector. Therefore, in order to avoid transaction costs, the direct allocation of 13 million m^3 per year to mines, imposing a price that corresponds to the their willingness to pay at x=13 million, would be preferable.

Finally, a policy that pushes mines to invest in water-saving technological innovation would be relevant in the studied case. Mines express their willingness to adopt technological solutions for water-saving, and the model has shown the benefits for the whole system in terms of economic efficiency, and environmental and social sustainability resulting from a reduction of water consumption by the mining sector.

This objective could be pursued through a balanced use of economic instruments (water charges and subsidies), aiming at modifying the mines behaviour with respect to water use within their production processes. A system based on the "user pays" principle, complemented by its corollary "those who invest in water saving techniques will be subsidised" (Farolfi & Montaigne, 2001) could be of interest in the analysed context.

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