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Economic Aspects of Water Management in the Drâa Region of Southeast Morocco

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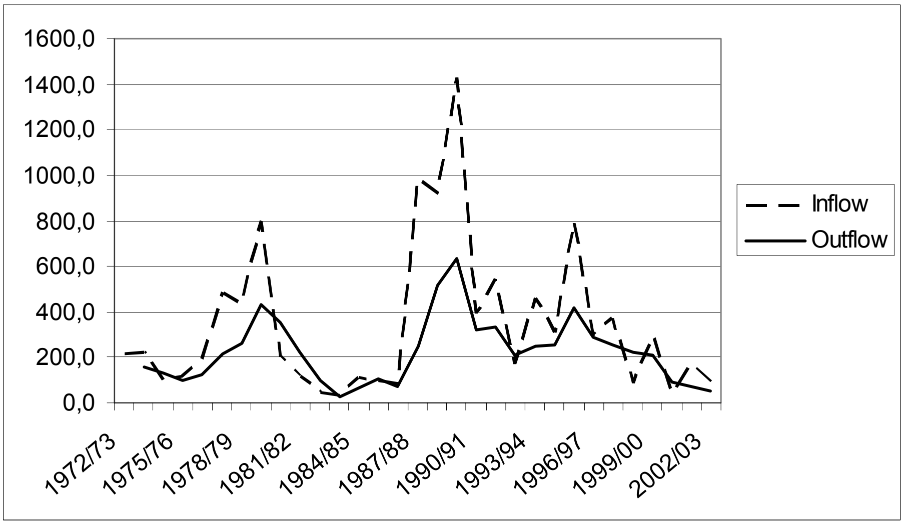
Water scarcity and distribution in the Drâa valley

The Drâa Basin in Southern Morocco is characterized by semi-arid Mediterranean desert conditions, extreme temperatures and low rainfall. Rainfall averages 346 mm per year, but downstream the barrage Mansour Eddahbi, however, average rainfall is varying around 104 mm. Figure 1 shows the water balance of the barrage. In- and outflows have varied remarkably during the last 3 decades with a declining trend in water supply since 10 years.

Figure 1: Water balance of the Mansour Eddahbi from 1972/73 until 2002/03



Source: Direction Générale de l'Hydrologie, Rabat

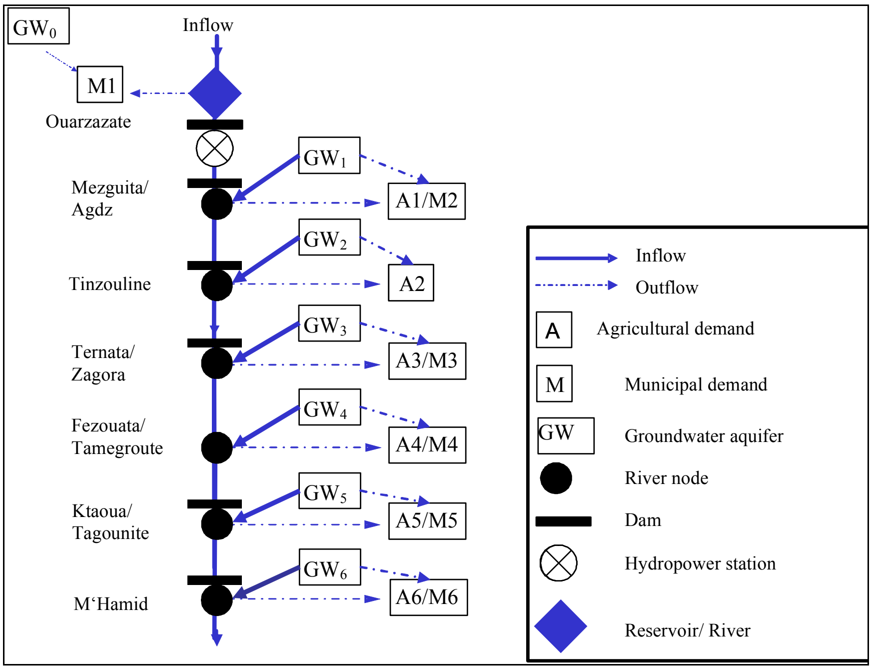
Agricultural production in the region is highly dependent on irrigation. Water for irrigation is mainly drawn from the Drâa River and its tributaries. But due to decreasing rainfall in the Higher Atlas and the following decrease in river flows, the exploitation of groundwater has become an increasing source for irrigation water, as surface water is not sufficiently available and is primarily used by the upstream oases. The overuse of groundwater is about to lead to increasing salinity problems for agricultural and household use. Moreover, the inter-sectoral competition for water is increasing. Agriculture is still the largest user of the resource, but tourism and the growing population especially in Ouarzazate will demand a higher share from a shrinking cake in the nearby future.

Since the establishment of the barrage Mansour Eddahbi in 1972, irrigation and the allocation of the Drâa's water resources is managed by the regional office of agriculture ORMVAO and by Water Associations of the region. Water allocation is predominantly carried out through so-called lâchers, amounts of water released periodically from the barrage, which are directed to the 6 oases south of the barrage via channels and ditches directly onto the field. By contrast, the management of groundwater use is only slowly developing. Water allocation policy is thus facing serious challenges. Currently, water is allocated mostly to agriculture with little attention being paid to efficient use. The calculations presented in this paper show that a continuation of the current policy could lead to the depletion of groundwater resources in the region, followed by the gradual abandonment of more and more agricultural area in the southern Drâa oases. This paper analyses the introduction of measures to prevent the overexploitation of the scarce resource.

The MIVAD model

The central tool of the research carried out in this paper is the integrated River Basin Model MIVAD (Modèle Integrée du Vallée du Drâa). Transferred from the Maipo Basin Model by ROSEGRANT et al. (2000), MIVAD combines hydro-agronomic and economic aspects in an interdisciplinary way. MIVAD acts as a centralized planner to allocate water resources of the Drâa Region to different users in an economically efficient manner to obtain the maximum utility for the region. Spatial relationships are represented in a node network representing different in- and outflows, barrages, reservoirs and water demand sites. Water distribution is modelled between the nodes. Figure 2 shows the organisation of the nodes in the river basin. The inflow starts with the amount of water determined exogenously from the Mansour Eddahbi barrage.

Figure 2: Network for the Drâa Basin in the MIVAD Model



Agricultural production is represented as an LP exercise involving six virtual "oasis farms". The response of crop yields on water stress is represented with a modified Penman-Monteith function according to FAO methodology. An economic component calculates the profits of the different water users, farmers, households and industry, and maximizes the utility. Hence, the overall aim is to maximize the benefits of all representative water users (profits of agricultural producers and industry, utility of private households) which enter the overall objective function of the model. Moreover, MIVAD contains a variety of constraints, bounds and balance equations related to hydrology (river, groundwater and reservoir balance), agronomy (crop yield response, area and cropping mixes) and general technological aspects (hydropower, pumping by public and private agents) all of which have to be controlled for. Salinity aspects are planned to be modelled in the further course of research work. The MIVAD Model is written in a GAMS Code (General Algebraic Modelling System). Up to now, the MIVAD Model was run for only one year, divided into monthly periods. Data sets used in the model are derived from official data sets as well as from the IMPETUS data base.

Simulation results for 2020

In order to make simulations over a certain time horizon possible, the MIVAD has been turned from a one-year model to a recursive-dynamic model covering the period from the base year 2000 up to the year 2020. The motivation for simulating management options for several decades was the fact that climate change as well as demographic and economic shifts occur too slowly to have an impact within one year. Even droughts usually are not one-year events, but rather the consequence of a series of dry years, particularly when there is the possibility to store water in reservoirs. The following trends drive the shifts in the course of the period under consideration.

- Less rainfall in the High Atlas means less water inflows into the reservoir. As a consequence, less irrigation water is available. For the simulation period, we assume a continuation of the relatively low and still declining inflows that have been observed during the last ten years, forcing the farmers to either abandon their fields or pump more groundwater. The inflows into the reservoir as well as the lateral inflows into the river system are assumed to decrease by 4 % per year.
- Population growth in the Drâa valley means that demand for drinking water will increase over the simulation period. We assume demand increases of 3.1 percent annually for urban and 0.8 percent for rural areas.

Consequences of cost-free river water use and unregulated groundwater use

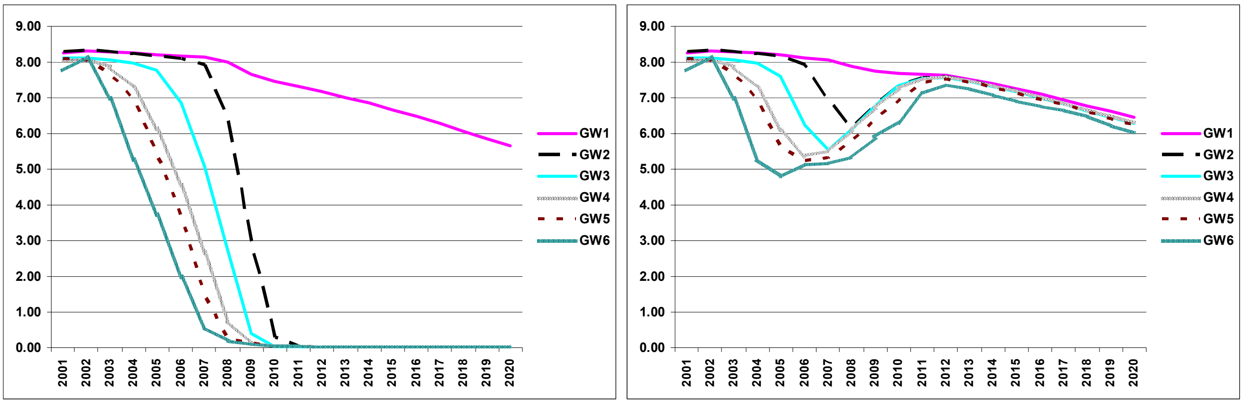
The stylised base run assumes that there is no water pricing for agricultural producers. River water can be used free of costs and charge, while private pumping of groundwater is free of charge too, but is assumed to cost 0.25 Moroccan Dirham (DH) per cubic meter. According to official sources, drinking water is charged with 2.54 DH/m^3. In the starting year 2000, water use is dominated by agriculture, which accounts for more than 95 percent of the total water use.
The most important result of the base run is that a continuation of the current policy would lead to a depletion of the aquifers in the lower four oases within a ten years (see figure 2). Even though this very quick depletion may be somewhat unrealistic, as it assumes that there are no local management mechanisms at all, it is nevertheless evident that this common property problem needs to be addressed more seriously in order to preserve the quantity and quality of water resources in the region. Agricultural shadow water prices (i.e. the marginal value of water as a productive resource in cropping) will climb from 0.48 to 0.96 DH/m^3. It has to be pointed out that this is still lower that the water price consumers are charged. This is the reason why the increase in the use of drinking water is hardly affected by the water scarcity.

Policy simulations

In order to restrain the excessive exploitation of groundwater resources, we tested two alternatives to the status quo. The first alternative simply consists of introducing a lower bound on the groundwater levels in the simulation model. This is aimed at simulating a tight monitoring and control of groundwater levels in each oasis, while the groundwater can still be used free of charge. As such, it represents a purely administrative solution to the problem. The second alternative is the introduction of a pricing system which charges those oases with rapidly falling groundwater levels a water price in the magnitude of the shadow water price of the previous period. It would then the (decentralised!) task of the local communities to distribute the costs among those farmers who actually used the groundwater. This second alternative is probably coming closer to a groundwater preservation policy which can be actually implanted, as, compared to pricing groundwater at each well individually and demanding charges from each farmer, this would have the advantage of relatively simple measurement at some central wells in each oasis.

Compared to the unregulated base solution, the lower bound on groundwater levels as well as pricing helps in keeping groundwater levels above certain minima. Figure 2 compares the results of the unregulated scenario with the pricing scenario.[1] The graph on the right hand side shows that groundwater levels fall somewhat below the minimum level of six metres before pricing leads to a recovery of the fills rates. The pricing scheme is designed such that as soon as groundwater levels would have completely recovered to the initial level of eight metres, the groundwater price would be set to zero again. This complete recovery is, however, not reached until 2020, probably because of the built-in increase in overall water scarcity.

Figure 2: Groundwater levels of the oasis aquifers in the Drâa valley under the under the base scenario and the scenario with groundwater pricing (in metres)



Unregulated (base) scenario

Groundwater pricing

Figures 3 and 4 display the development of average shadow water prices in the basin and the level of the water price charged from those oases which violate the minimum aquifer levels. The unregulated base solution reveals a development of water value in certain steps. Until the depletion of the first aquifers in 2007, shadow prices are stable. The period during which one aquifer after the other is almost running dry is then marked by almost doubling shadow prices (until 2011), followed by another period of stability on a higher scarcity level lasting until 2017. Here, land use in the oases can be hardly reduced any further, as it would involve reducing the area under date palms, the latter which is prohibited in the model in order to preserve the capital

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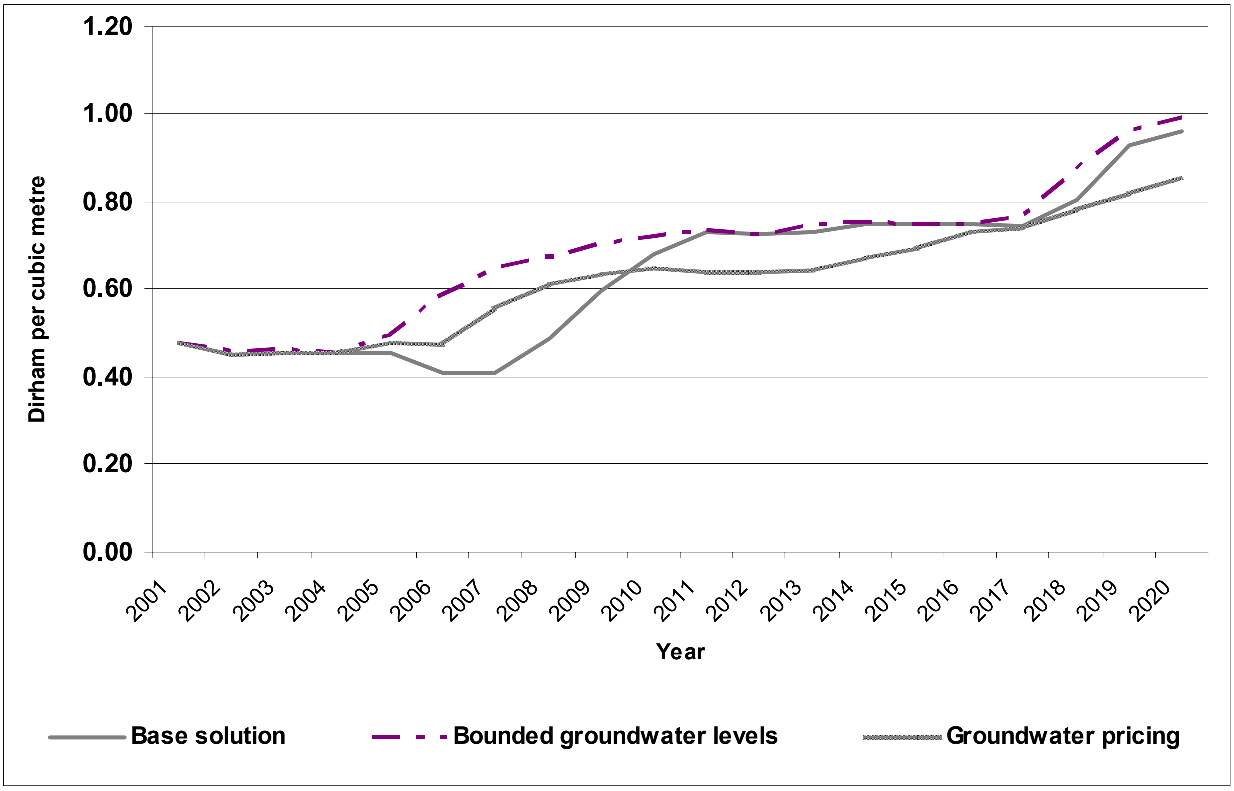
[1] Only the unregulated solution and the pricing alternative are displayed in figure 2, as the lower bound simulation's results simply let the groundwater levels fall to the minimum level, beyond which no change occurs any more.

invested in these perennial crops. The scenario which simulates the administrative prohibition of groundwater depletion produces higher shadow prices particularly during the period where the first aquifers would have been driven to zero levels. After 2011, shadow prices under this scenario are again in line with the unregulated scenario: in both cases, groundwater use is simply restricted to the monthly natural groundwater recharges (lateral inflows and inflows from upstream aquifers), and only the groundwater levels differ. The pricing solution, by contrast, leads to a somewhat lower water price development path; as some of the water used for irrigation is now charged a real price, the marginal value of the rest of the resource is driven down a bit.

Figure 3: Development of the average shadow water price for the whole Drâa Basin (in Moroccan DH per cubic metre)



The magnitude of the groundwater charge oriented at the shadow price of the previous year can be seen in figure 4 for those oases where groundwater use is priced. As the agricultural models representing the oases differ only slightly from each other (the fixed area covered with dates differs across the oases to some extent), the marginal value of irrigation water is relatively similar, and thus the water charge.

Figure 4: Groundwater charges for those oases where minimum groundwater levels where violated (in Moroccan DH per cubic metre)

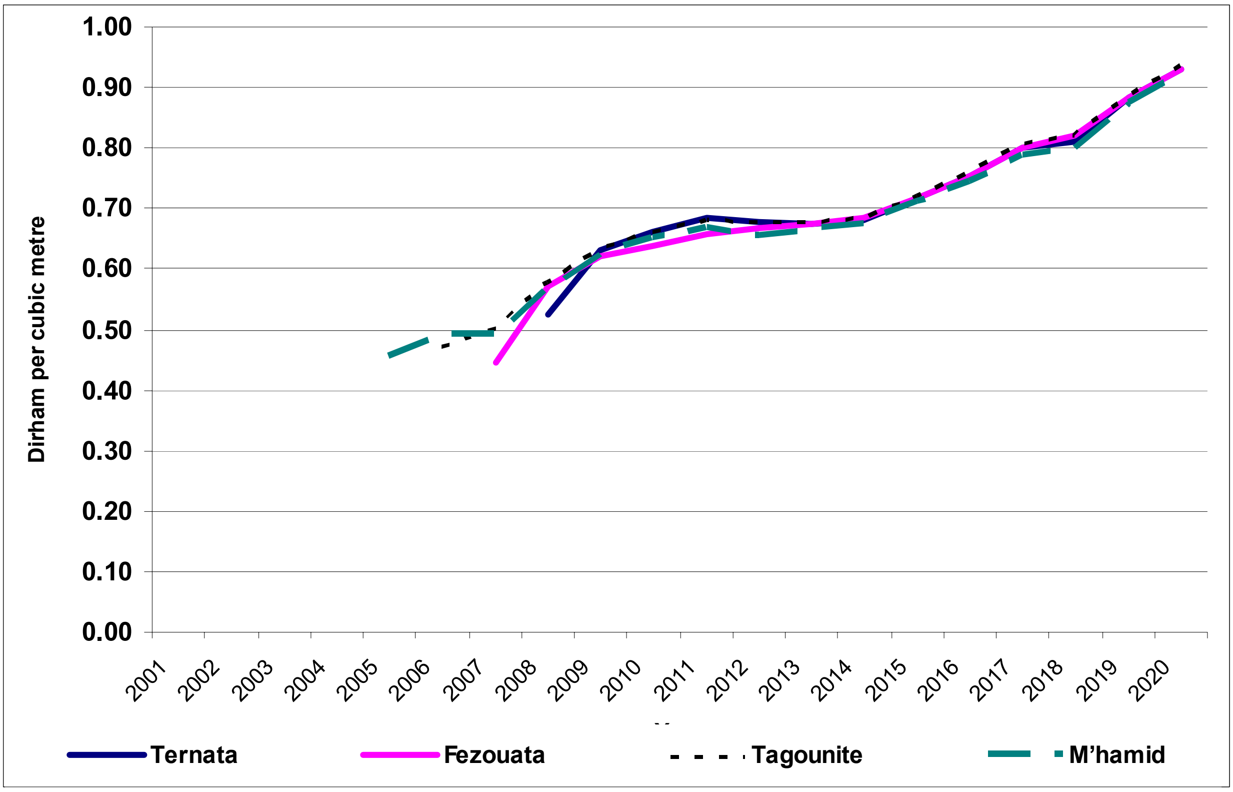
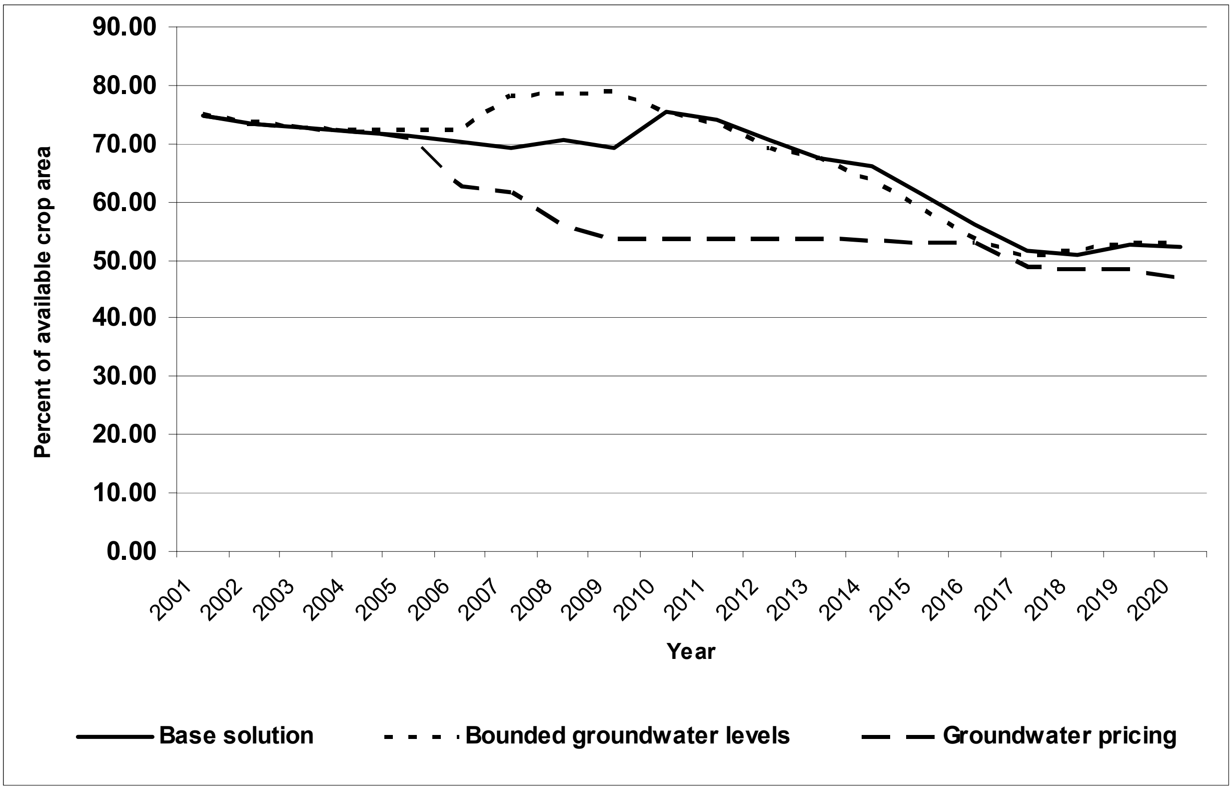


Figure 5: Use of available crop area in % under increasing water scarcity under the different scenarios



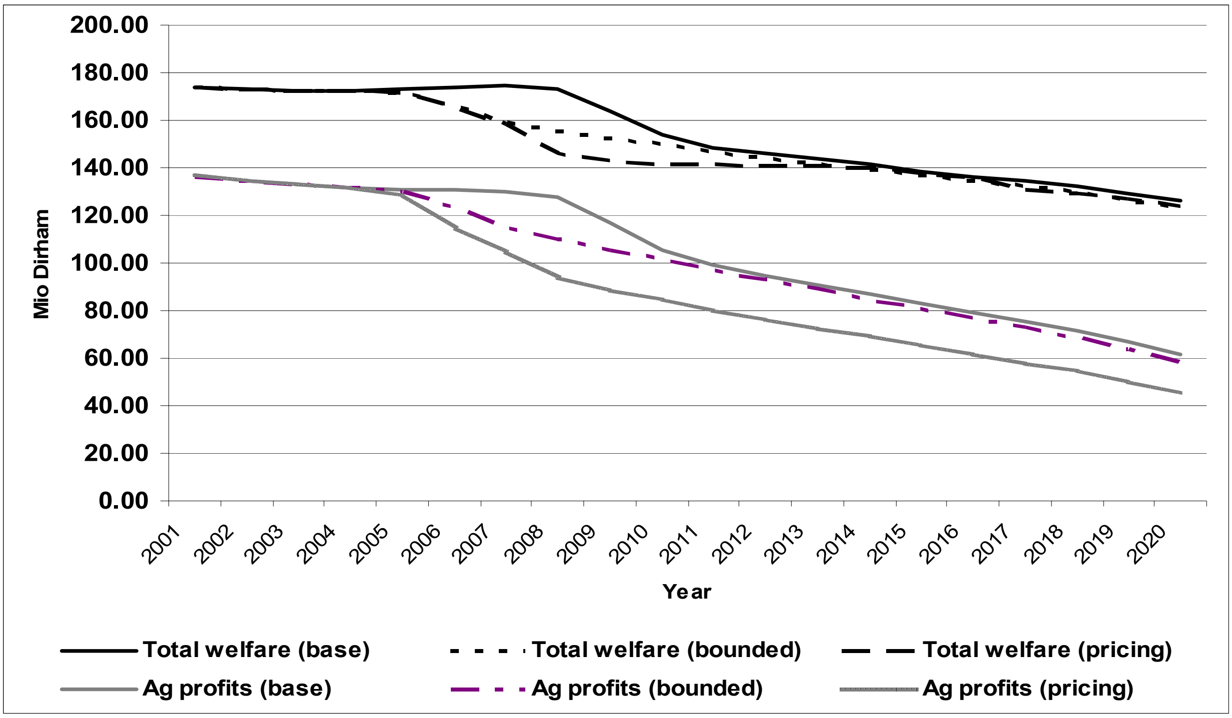
The introduction of groundwater regulation must inevitably lead to reduced agricultural activity, as shown in figure 5 comparing the three scenarios. Also, the unregulated and the administratively bounded solution differ only during a certain period during which the groundwater levels are still allowed to be driven down in the unregulated scenario. The groundwater pricing scheme, however, leads to a marked reduction in the share of available land that is actually used, at least as long as no water-saving technologies are introduced. Even though all scenarios arrive at roughly the same use coefficient at the end of the simulation period, under the pricing option land use goes down to only slightly more than 50% after half of the time already, remaining largely stable from then on.

Table 1 shows the average gross margins resulting from the simulations until 2020. The unregulated version yields the highest gross margins per hectare, followed by the administrative solution and the pricing solution. The pricing solution also produces the most pronounced differences in farming profitability, which is a probably a crucial point regarding the acceptability of such a pricing scheme.

Table 1: Impact of alternative water policies on agricultural gross margins in the Drâa oases (thousand DH per ha)

	Base run	*Lower bounds on groundwater levels*	*Groundwater pricing*
Agdez	3.70	3.55	3.82
Tinzouline	3.67	3.33	4.28
Ternata	3.45	3.25	3.06
Fezouata	3.26	3.08	2.81
Tagounite	4.01	3.94	2.77
M'hamid	3.55	3.45	3.46
Basin average	**3.61**	**3.43**	**3.37**

Figure 6: Development of basin partial welfare and agricultural profits under the different scenarios (in Million Moroccan DH)



Finally, figure 6 presents the welfare implications for the Drâa basin for the different scenarios. As for the overall welfare implications, these mainly differ in the period where the aquifer levels can be run down in an unsustainable manner or not. In the periods after 2012, basin welfare is again relatively similar across scenarios. The differences in total welfare might be taken as an approximation of the costs involved in preserving sustainable groundwater levels in the Drâa basin. However, this criterion is still quite coarse, as, for instance, the costs of monitoring and enforcement in both the 'administrative' and the pricing solution are not known. Agricultural profits are also depicted in the graph, and it can be seen the pricing solution would probably be the one least liked by farmers. The welfare calculation for the whole basin contains the sum of the water charges. Provided that these could be used to support investments in water-saving technologies, the resistance of farmers against pricing might be overcome.

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