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Conflicting Policies: Agricultural Intensification *vs.* Water Conservation in Morocco

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Acronyms

ABH	Agence de Bassin Hydraulique (river basin agency)
Bm3	billion cubic meters
CESE	Conseil économique, social et environnemental
CSEC	Conseil Supérieur de l’Eau et du Climat
CIE	Comité Interministériel de l'Eau
ET	Evapotranspiration
FDA	Fonds de Développement Agricole
MD	Moroccan Dirham (one euro ≈ 10 DH)
Mm3	million cubic meters
ORMVA	Office de Mise en Valeur Agricole (regional irrigation administration)
PDAIRE	Plan directeur d'aménagement intégré des ressources en eau (basin master plan)
PMV	Plan Maroc Vert
PNEEI	Programme national d'économie d'eau en irrigation

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1. Introduction: a water-dependent economy and policy worries

Reports or presentations about water problems in Morocco invariably start with concerns about dwindling per capita water endowments, and water indicators that allegedly point to growing water stress or scarcity, begging a resolute policy response. They also generally refer to the outstanding achievements of the Moroccan water sector, that "has been lauded and recognized by the entire world" (Benzekri, 2006). The success of the Moroccan water sector is conventionally associated with a number of achievements. These include the foresight of King Hassan II's 'Large Dam program' in ensuring a healthy storage capacity for the nation, as well as the extent and quality of urban water services, and the technical capacity of its water professionals. Also praised are a long-term planning policy launched in the early 1970s, and a 'state-of-the-art' institutional framework and legal arsenal, most prominently Law 10-95 enacted in 1995 (and updated in 2016), which consolidated integrated, participatory and decentralized water resources management through the creation of 'river basin agencies' (ABH in what follows) (SECEE, 2009). These policies endowed the country with 140 large dams, an area equipped for irrigation of approximately 1.5 million hectares, the satisfaction of domestic, industrial and tourism water needs, the improvement of flood protection, and the development of hydropower production (SECEE, 2009; El Gueddari and Arrifi, 2009).

The economy is dominated by the service sector, with a 55% share of GDP in 2011, against 30% for industries and 15% for agriculture. The role of agriculture in the economy, however, is enhanced by the fact that it employs 44% of the active population of the country (United Nations, 2014). All economic sectors depend heavily on water resources that are now

> under threat (…). For Morocco, it will be a key to its development in the coming decades. Concerns are mainly attributable to the combination of the growth in demand and the increasing scarcity of the resource. With the reduction in rainfall observed, runoff fell by 35% in 30 years. While the public irrigation area grows by 2.3% per year, water supply declined on average by 2% annually between 1991 and 2002. (…) Water will become the key to the development of the country: its effective and efficient management is the main challenge (HCP, 2007).

Groundwater resources are a particular concern. According to estimates admittedly based on a crude knowledge of actual abstraction, about 5 billion m3 (Bm3) of water are abstracted against a renewable potential of 3.4 to 4 Bm3. According to the Minister for water, "groundwater resources provide drinking water to 90% of the rural population and to almost 40% of the total area irrigated in the kingdom, contributing to more than 50% of the economic value-added generated by all irrigated areas" (Maroc.ma, 2014).

The bulk of the kingdom's water resources is consumed by agriculture. The use of water in agriculture is invariably described as wasteful, the blame being put on 'traditional' gravity irrigation "which wastes large amounts of water" and does not allow one to evaluate the quantities applied accurately (Sghyar, 2013). A standard indictment of this practice consists in emphasizing that "the overall efficiency of the use of water in irrigation, including the conveyance of water and application on the fields is currently of the order of 40%, which means that less than half of the water delivered to farms currently reaches the crops" (World Bank, 1998).

Worldwide, water shortages in general and problems of groundwater overexploitation in particular, have spurred calls for 'improved efficiency'. A standard and almost knee-jerk policy response has been the promotion of micro-irrigation. In countries where irrigation is key to agriculture, most particularly in the Mediterranean region, there is hardly an agricultural policy that does not promote or subsidize micro-irrigation as a key to achieving efficiency and poverty alleviation. In Tunisia, the National Program for Water Savings, established in 1995, offers subsidies for farmers of 40 to 60% of the total investment costs for water saving irrigation technologies (Frija et al., 2014). In Algeria, a program adopted in 2000 (PNDA) provided subsidies for micro-irrigation (among other things) as high as 100% (Amichi et al., 2015).

Likewise, Moroccan policymakers have given a strong priority to the dissemination of micro-irrigation. Taxes on the import of equipment for micro-irrigation have been reduced or canceled since 1982 (MAPM, 2007a; Laamari et al., 2011). In the 1990s subsidies offered by the FDA (*Fonds de Développement Agricole*, established in 1986) averaged 17% of the investment costs in micro-irrigation. In 2002 a new decree raised the level of subsidies to 30%-40% (depending on the water status of the river basin), and extended this subsidy to all components of the project (including wells, pumps and intermediate storage ponds). Shortly after, a National Program for the Development of Micro-Irrigation was launched with a target of 114,000 ha. In five years this program had only attained 39% of the stated objective (El Gueddari and Arrifi, 2009), with 75% of the conversion observed actually achieved through the pre-existing FDA. Faced with the evidence that few farmers yet had the capacity to invest (although at the same time private investments without subsidies were taking place, like in the coastal Chaouia), in 2006 the government raised the rate of subsidies to 60%. Yet the Prime Minister declared that "efforts to establish an efficient demand management did not live up to [our] ambitions" and that "the government was ready to launch a large national program for water savings, a key measure of which would be the expansion on a large scale of efficient irrigation techniques" (MAPM, 2007a). In 2007 the National Program for Water Savings in Irrigation (PNEEI) was established.

The PNEEI adopted ambitious targets. It seeks to achieve the conversion of 550,000 ha of land irrigated by gravity or sprinkler to drip irrigation in 15 years, at the cost of 37 billion MD (~3.7€ billion). Of this conversion, 72% would involve large-scale public irrigation (including some individual farm conversions and the modernization of the collective distribution of pressurized water through pipes), with the remainder being devoted to private individual irrigation. Technical change was to be accompanied by technical advice on irrigation practices, crop choice, and strengthened linkages with the agro-industry and export markets (MAPM, 2007b).

The predicted outcomes of the program included water savings varying between 30% and 50% (with a total of around 1 Bm3 'saved')[1], an increase in yields of up to 100%, increases in job creation, rural incomes, and service fee recovery, a reduction in the energy demand of the irrigation sector, and —rather optimistically— a reduction in the overexploitation of aquifers (El Gueddari and Arrifi, 2009). The PNEEI was to be "conducive to a revolution in Moroccan irrigated agriculture, not only with regard to irrigation water use efficiency, but also to productivity and competitiveness" (El Gueddari and Arrifi, 2009).

In 2008, the overarching Plan Maroc Vert (Green Morocco Plan, or PMV) was launched, incorporating the PNEEI. Three years later, the PMV would finally raise the level of subsidies to 80% for large farms (areas over 5 ha), and 100% for small farmers (below 5 ha). In less than 10 years the support to micro-irrigation shifted from 17% to 100% in subsidies.

In 2008, the Monitor Group (2008) proposed the conversion of 900,000 ha by 2030, at an estimated cost of 35 billion DH and with predicted water savings of 1.6-1.7 Bm3. Surprisingly, however, in the National Strategy (Royaume du Maroc, 2011) presented by the government in 2009, the potential for water savings in the irrigation sector inflated to 2.5 Bm3 by 2030, this being achieved by conversion to drip irrigation (2 Bm3/year), improving conveyance efficiency,

[1] More precisely, the PNEEI project document has a water saving target of 826 Mm^3/year, including 514 Mm^3/year in large scale public irrigation schemes ('reconversion') and 312 Mm^3/y in groundwater-based individual irrigation (MAPM, 2007b).

volumetric pricing and awareness raising campaigns. The same number was repeated in 2014 by the *Conseil Economique, Social et Environnemental* (CESE, 2014).

By 2014, the annual rate of conversion to drip irrigation had been increased fivefold, with an average of 50,000 ha of land per year, compared to 10,000 ha before the PMV[2]. According to data provided by the Department of Agriculture, the agricultural GDP saw an average increase of 7% per year, or a jump of 57% from 2008 to 2015. During this same period the income of farmers quadrupled, from 2000 to over 7800 DH. These results, however contested they may be, were achieved by massive investment, estimated at close to 90 billion DH (around €9 billion) during the period 2007-2015 (Challenge, 2016). With regard to water savings, in 2016 the Ministry reported that the conversion to drip implemented so far had yielded savings estimated at 800 million m^3 (Mm3), and that "farmers had been able to diversify their production systems and achieve up to three times more production with half the water" (quoted in L'Economiste, 2016).

This report does not address the technical/financial performance of the PMV in general[3], nor that of agricultural intensification in particular. The working hypothesis is that drip irrigation and other measures do indeed have a positive impact on land and water productivity and contribute to what is considered the 'modernization' of Moroccan agriculture. At least a part of Moroccan agriculture is able to diversify into cash crops and perhaps better compete in international markets. This certainly raises new questions around the induced vulnerability to fluctuating world markets, drop of domestic prices due to overproduction, social differentiation, or the higher risks that come with intensification (FAO, 2012). Our focus here, however, is limited to what this modernization 'does' to the water resource, whether claims to water savings are scientifically grounded, and to what appears to be a contradiction between agricultural and water resource sectoral policies.

2. Water-saving policies: application on the ground

1.1 Drip irrigation and what it (really) does

In Morocco, as elsewhere in the world, the rhetoric of water savings associated with micro-irrigation has been challenged by a growing body of evidence from the field. Observations and analyses carried out at the plot, farm and system levels have undermined common wisdom. In this section we present the available evidence on Morocco and bring in literature on international experience. For analytical purposes, we distinguish successively between several types of changes in farming practices associated with the adoption of drip irrigation.

Firstly, if cropping patterns are kept unchanged at the plot level, it remains uncertain whether the transition to micro-irrigation translates into a reduction in the quantity of water *applied*. The amount of water applied onto a unit of land is normally substantially reduced by the technology itself, but a closer look at how farmers use drip systems in the Saïss and elsewhere showed that overirrigation is common, with plot-level efficiency varying between 25% and 90% (Benouniche

[2] Abdelhafid Debbarh, President of ANAFIDE (*Association Nationale des Améliorations Foncières de l'Irrigation, du Drainage et de l'Environnement*), quoted in Menara.ma, 2014.

[3] This is not the place to discuss the merits of the PMV, beyond its impact on water resources. Early critiques have pointed to the reinforcement of capitalistic agriculture to the possible detriment of family farming (e.g. Akesbi, 2012, 2014), with negative social impacts emphasized by UN envoy Hilal Elver (Bentaleb, 2015), at the very time the media was reporting "the vibrant tribute to the PMV of the FAO" (La VieEco, 2015). For an uncompromising deconstruction of the achievements claimed by the PMV see Salem and Ait Benhamou (2016).

et al. 2014b)[4]. Similar ranges have been found in private irrigation in Berrechid (46% to 78%), the Gharb (48% to 88%) and in the coastal Chaouia (38% to 89%) by research quoted by Benouniche et al. (2014b).[5] Sraïri (2015) also reports that high rates of subsidies (80 to 100%) for investment in drip irrigation have accelerated the rate of adoption, but without ensuring effective technical control. In the Doukkala it was observed that farmers used to gravity irrigation were applying water (daily) by drip until pounding water became visible (FAO, 2012). There are also widespread problems with filtration and the clogging of drippers (FAO, 2001). A similar situation is observed with inappropriate fertilization (overapplication), which belies the predicted gains in terms of fertilizer efficiency and reduction in losses to the aquifer (ibid.). A World Bank project evaluation (2009) recognized that the technology is frequently misused and comes with technical requirements, such as cleaning and servicing the nozzles, changing dripper lines, mastering fertigation, etc.

To achieve a uniform supply to crops, distribution systems need to be properly designed and adequately maintained. In practice, this often fails to be the case. Other problems of efficiency may be linked to the farmers' lack of know-how, or more simply to the fact that saving water is not really a concern. Even in systems considered advanced, such as the Capitanata in Italy (Levidow et al., 2014), or in the US (Burt, 2004) or Spain (Salvador et al., 2011) these problems may add up and account for a performance lower than expected. Theoretically, these practices could be improved through extension services or other forms of technical advice, but this is easier said than done. The plot-level efficiencies currently observed in drip-irrigation systems vary widely and are often far short of the theoretically predicted values. The present empirical data is inconsistent as to any reduction in the (gross) quantity of water that is *applied*[6], although it is apparent that capital-intensive (larger) farms, managed by trained technicians or engineers, perform better than small farms with poorly designed systems overall (see FAO, 2012; Chiche, 2010).

The second issue is the impact of drip on actual evapotranspiration (ET) at the plot level, when cropping patterns are unchanged. For a given plot, drip-irrigation may not significantly affect the overall *depletion* of water, and may even increase it. Two effects tend to cancel each other out:

a) firstly, micro-irrigation does not necessarily reduce (non-beneficial) soil evaporation significantly (this depends on several factors such as the density of the drippers; whether the crops cover the soil[7]; the texture of the soil, etc.). Less soil is wet but it is wet for longer periods. Traditional olive groves on soil with good capacity in the Haouz can be irrigated by gravity every three weeks, against twice a week or more with drip.

b) secondly, crop transpiration increases due to more frequent and timely irrigation (Burt et al., 2001[8]; Ward and Pulido-Velazquez, 2008; Perry et al., 2009). This is even more the case in systems that are water short and where farmers practice deficit irrigation, or where irrigation by

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[4] Over-irrigation is mostly due to non-uniform pressure and drip discharge (caused by poor system design or clogging of some drippers), leading farmers to apply more water to ensure that disadvantaged areas receive enough water; or an attempt by farmers to avoid any stress that would cause yield reduction (Benouniche et al., 2014b).

[5] Benouniche et al. (2014a) also showed that farmers often adopt drip irrigation as a way of improving their social status. "There is no social pressure to irrigate carefully to save water; only the state explicitly links the use of drip irrigation to saving water".

[6] Especially because the quantities of water delivered by the ORMVAs do not tell us anything about the amount of complementary water that is sourced from groundwater (half of the needs, as an order of magnitude).

[7] Thorenson et al. (2013) studied ET in vines and tree crops in California through remote sensing. These are the crops for which reduction in non/little-beneficial soil evaporation is more likely, as opposed to field crop which cover the soil. They found a reduction of ET of less than 6% on average.

[8] More generally, see the wealth of papers available at www.itrc.org/reports/index.php.

gravity was inefficient, for example due to poor land leveling or practices. In Morocco this is frequently the case in most ORMVAs (regional irrigation administrations). However, it may be less so for individual groundwater-based irrigation for which water is available on demand.[9] A study in the Tadla Scheme using satellite imagery and energy balances (Riverside, 2010) compared 12 plots planted with citrus, five plots irrigated by gravity and seven by drip, and found only 1% difference in consumption (ET).

In New Mexico, satellite imagery allowed a comparison of ET in plots growing the same crops but irrigated by gravity or drip, pointing to water consumption in the later 8%-16% higher than in the former, depending on the type of crop (Intera, 2013).

Working in California, which has long been compared with Morocco in terms of irrigated agriculture, Burt et al. (2001) showed that it was extremely challenging to draw comparisons of soil Evaporation (E) and crop Transpiration (T) for different types of crops, crop cover/density, soils and technologies, with significant discrepancies between situations. In certain cases, for example drip in almonds in Westlands Water District, ET was estimated to be 10%-15% higher than for other irrigation methods. In situations with soils with good retention capacity and/or frequent wetting both E and T are likely to be higher: "when one combines possible higher evaporation with almost certain higher transpiration, the overall ET can be expected to be higher under drip/micro than for surface and sprinkler methods in many cases." ET is often basically unchanged, but the distribution of E and T varies. Importantly, Burt et al. (2001) found that in California E represented only 11% of annual ET. Therefore, changes in E are unlikely to exceed increases in T, and the conclusion that modernization is ET-neutral is conservative. The recent literature review by Perry and Steduto (2017) flatly found "no documented examples of water savings for field crops in terms of consumptive use" and confirmed the "null-hypothesis". It can be safely concluded that, overall, it is not at the level of total ET that potential savings can be identified.

The increases in yields announced by the government[10] and farmers also suggest that actual crop transpiration has increased, although it is not easy to distinguish between what is to be ascribed to intensification, expansion and good rainfall, respectively.

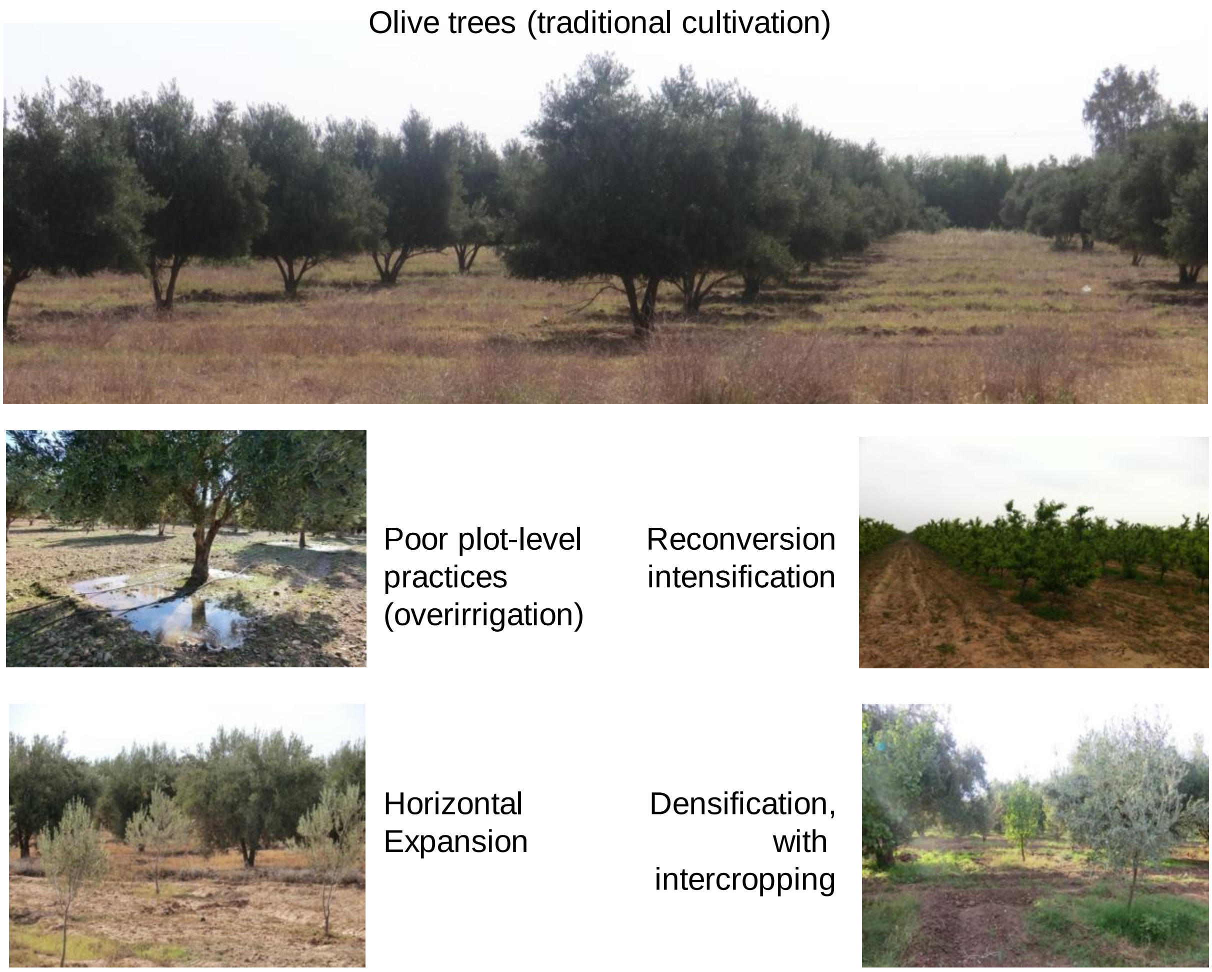
A *third issue* refers to changes in cropping patterns that are often associated with the shift to drip. Drip technology is generally part of an intensification package that chiefly makes sense for vegetable or fruit trees (which partly explains the better added-value drawn from water that has been reported; see L'Economiste, 2016).

- With drip, the farmer can first choose to 'densify' his orchard or olive grove, by adding (young) trees in the middle of old trees (The density of olive trees is typically multiplied by four). In the Souss, the density of clementine moved from 200 to 500 and even 800 trees/ha (BRLi and Agroconcepts, 2013).
- The farmer can also adopt mixed-cropping, e.g. adding fruit tree lines between olive trees (see Figure 1).
- He can also uproot his old trees and plant his plot anew with a higher density of trees (either olive or fruit).[11]

[9] Although this will not hold for areas where the drop in the aquifer and the competition between farmers during periods of peak demand restrict the number of hours during which farmers can pump (pumping has to be discontinued for the water table to come up again).

[10] According to FAO (quoted in La VieEco, 2015), during the first five years of the PMV the cultivated area has increased by 10% and agricultural production (Ag.GDP) by 43%. Between 2008 and 2014, 410,000 ha have been equipped with drip irrigation systems, against a target of 550,000 ha for 2020.

Figure 1. Changes induced by microirrigation that result in higher water consumption (Haouz, Marrakech)(Tanouti et al., 2016)



- In other cases, the adoption of drip can give rise to a full conversion of production, e.g. from cereals to arboriculture (olive trees, apricot, etc.) characterized by far higher water requirements distributed throughout the year.[12]

In the Souss-Massa, it has been observed that "the public-private partnership developed on the lands held by public organizations has often been an opportunity to intensify plantations and, correspondingly, to increase groundwater abstraction" (BRLi and Agroconcept, 2013). FAO's (2012) experimentation in the Doukkala with farmers converting to drip showed that the amount of water applied decreased by 14% to 50% (for different crop mixes), but that *consumption* at the farm level may increase due to shifts in cropping-patterns and greater cropping intensity (+20%), since farmers may make use of collective storage facilities and irrigate more frequently. Kuper et al. (2012) also found that in the Tadla scheme the use of groundwater has clearly been conducive to both intensification and diversification, while opening the way to using drip irrigation. The same was observed in the Saïss (Kuper et al., 2017).

[11] These trees will grow under a drip-irrigation regime and will develop a much shallower root system, making them more vulnerable to water shortages and less able to exploit rainfall that infiltrates into the soil profile

[12] A common fallacy is that farmers will shift to 'crops with higher value and lower water requirements', while in reality water requirements may or may not be either. The shift to tree plantations, which is the most common in Morocco, clearly leads to higher water requirements.

What can we learn from countries with similar climatic conditions? Fernandez Diaz et al. (2014) found that water requirements in five schemes of the Guadalquivir basin had either increased or decreased, depending on the crop mix, but that due to the increase in citrus plantation there will be a 9% increase in ET by 2020, when the trees have grown and reached maturity (Berbel et al., 2014). Sanchis-Ibor et al. (2015) found that in the Mijares river, Spain, cropping patterns (*citrus*) had not been affected by the shift to drip (water application was substantially reduced, but actual ET at the plot level was not measured). González-Cebollada (2015), however, showed that in seven schemes[13] in Spain per-hectare water consumption had increased by between 4% to 45% due to intensification and a shift to crops with higher water requirements, notably trees. Likewise, Sese-Minguez et al. (2017) found that in the Cànyoles watershed drip irrigation was associated with intensification, a shift to trees and expansion into former rain-fed areas. The clear impact of a shift to drip on water consumption even led the US state of Montana to sue Wyoming, claiming that farmers who had installed high-efficiency irrigation systems were reducing the amount of water in the Yellowstone River that should have flowed to Montana, in violation of the interstate compact (Anderson, 2013; MacDonnell, 2012). Ward and Pulido-Velazquez (2008), Playán and Mateos (2006), Contor and Taylor (2013) and Willardson et al. (1994) all provide further discussion and evidence of this effect.

Where the density of trees is increased, or intercropping is developed, as is frequently observed in Morocco, there is no question that overall crop requirements are increased. In addition, drip is largely associated with the expansion of vegetable[14] and tree plantations. For example, land use forecasts for the Gharb consider a reduction of cereals by 127,000 ha in favor of olive, citrus, fruits, sugar beat and fodder – all crops with higher water requirements (ABHS, 2011). These facts combined point to a likely increase in the water *consumed* at plot level. Furthermore, as water becomes more valuable through the production of high-value crops, farmers have enough capital to deepen their well whenever necessary (Perry and Steduto, 2017). The shift to cash crops and more profitable agriculture removes any 'brake' that might result from increased pumping costs.

The fourth issue is whether the possible reduction in the amount of water applied by unit of surface area frees water to expand cultivation. Since drip systems are most frequently associated with individual wells, the water available is defined by the capacity of the well and is therefore not changed in the short term. The farmer may be led to expand laterally to increase the irrigated area into plots that are either rain fed or left fallow because of insufficient supply, whether these plots belong to the farmer or are rented from neighbors.

This phenomenon is typical of regions where water is scarce relative to land, and has indeed been observed for example in Spain (Playán and Mateos, 2006; WWF/Adena 2015, Berbel et al., 2014), Morocco (Tanouti et al., 2016; Jobbins et al., 2015), Tunisia (Feuillette, 2001; WaterWatch, 2008), India (Moench et al., 2003; Bhamoriya and Mathew, 2014; Fishman et al., 2015), Pakistan (Ahmad et al., 2014), Israel (Dinar and Zilberman, 1994), China (World Bank, 2015), or the US (Huffaker et al., 2000; Huffaker and Whittlesey, 2003; Walton, 2014).[15]

Tanouti and Molle (2013) have observed particular instances in the Haouz, where farmers who did not cultivate/irrigate all of their plots could easily enlarge their plantations (see Figure 1), while Jobbins et al. (2015) report on this phenomenon in Chichaoua and Souss-Massa, and BRLi

[13] Including the Bembézar scheme studied by Rodríguez Díaz et al. (2012), who found an increase in ET of 20%.

[14] See for example the debate around the interdiction of watermelon cultivation in the Souss, believed to "absorb half of the water" in the Zagora region (Bentaleb, 2016).

[15] Most of these observations, however, are casual and have rarely been quantified or documented in a detailed way, which would require monitoring of a sample of farms in those specific environments.

and Agroconcept (2013) in the Souss. With the exception of a study on 4,000 ha in the Saïss Plain (Kupper et al., 2017), and a case study by van der Kooij et al. (2015), showing in particular expansion into rain fed areas, this phenomenon has not been studied extensively. We may assume from multiple passing observations that this can also be seen in other areas of Morocco but more evidence is needed to quantify this phenomenon.

If the farmer is served by a collective irrigation network (in areas of public '*grande hydraulique*'), adjacent land may not always be available for expansion and farmers are likely to adopt one of the intensification strategies described above.

The *fifth issue* concerns the reduced return flows and the resulting impact on their appropriators. Since, for those reasons stated above, water consumption at plot level can be assumed to have increased, the return flow to the drainage system or aquifer has been reduced. This holds irrespective of whether the amount of water applied at the plot level has been maintained or reduced. In the vast majority of cases (most notably the southern deficit basins) this translates into a *worsening of the net balance of the aquifers*.[16] Indeed, if supply of surface water is maintained, or even reduced, on the one hand, while water consumption is enhanced, on the other, then this can only result in reduced return flows (to rivers or, predominantly, aquifers).

In non-stressed systems (for example, basins with surplus, such as the Loukkos or Sebou, outside the Saïss) this can be beneficial: pumping costs are reduced; agrochemical pollution is reduced, and so on. But in situations of 'basin closure' (see Keller et al., 1998; Molle et al. 2010), where users have gradually tapped the water available at all levels of the hydrological cycle, these 'losses' are in fact likely to contribute to the water appropriated by other users abstracting surface and groundwater (Seckler, 1996). In all irrigation schemes where groundwater is not too saline (for example, in the Saïss, Tadla, Haouz and Souss. See the Appendix) the water 'lost' by percolation of irrigation water – as well as recharge from rainfall – has long been *more than fully* tapped by thousands of wells. Typical drops in water levels of 0.5 to 3 m/year signal abstraction levels *greatly in excess* of the recharge (let alone any defined 'safe yield' – see the example of the Tadla and the Haouz in the Appendix).

Some water can probably be saved in coastal irrigation schemes. The Loukkos scheme is not water-short and return flows have built up the water table. However some private well irrigation has now developed based on this resource. The same situation can be observed in the Gharb, where the Mnasra coastal aquifer system has been massively tapped in the past 15 years (Bouya et al. 2011). This aquifer has been fed by infiltration from nearby public schemes, providing another example of how 'losses' are actually often reused.[17] In the Doukkala, some wells are tapping infiltration water but quality is generally degraded (Rahoui et al., 2000; Khyati, 2000). In this instance limiting seepage through drip is beneficial in terms of resource conservation.

Where no or little water goes to sinks, the challenge is to *manage evapotranspiration*. A classic study on Luancheng County, in Hebei province, China, has illustrated that in such cases *evapotranspiration* is what needs to be reduced (what is indeed partly done through adequate crop choice, plastic mulching and all other on farm techniques) and not water abstraction per se,

[16] As surface water is almost fully allocated (except in the Sebou basin and north of it), overconsumption is eventually shifted to groundwater and the water tables in the Saïss (part of the Sebou river basin), the Haouz, the Tadla, the Souss-Massa, coastal and oasis aquifers are good indicators of over-allocation and unsustainable use.

[17] According to ABHS (2008), the balance of the Gharb aquifer is already negative (-31 Mm3) and the discharge to the river and the sea is only 20 Mm3. Note that half of the remaining 100,000 ha to be equipped with public irrigation networks are *already* irrigated by individuals tapping groundwater (and also local wadis)(ABHS, 2006).

since return flows go back to the aquifer[18] (Kendy et al., 2004; see also Wu et al., 2014; Yan et al., 2014).

A subsidiary question is what happens to the water 'saved' at the system level, if allocation is reduced based on predicted higher plot-level efficiencies. This water will likely be reallocated to another consumptive use[19] and the overall depletion of water will be increased. But, in any case, at present the nine regional irrigation administrations (ORMVAs) cover only 60% of the requirements of their command areas on average (and only 40% in the water-short basins of the South: Oum er-Rbia, Tensift and Souss-Massa), so they are hardly in a position to effectively reduce farm allocation[20]: in the Tadla scheme farmers having adopted drip irrigation were given a quota of only 3000 m^3/ha (Kobry and Eliamani, 2004), half of the theoretical normal value but more than the average historical actual delivery. In any case, the shortfall would continue to be sourced from wells should the supply be significantly curtailed. Consequently, as many farmers also have access to groundwater, such system-level 'gains' are likely to translate into an equivalent depletion of the aquifer.

Conversely, where unsustainable groundwater-based agriculture is relieved by the transfer of surface water the additional water may simply promote expansion. In the El Guerdane project in the south, water transferred by a pipe was supposed to provide 50% of crop needs and to substitute groundwater. But no restrictions have been placed on existing wells, and irrigated areas have therefore expanded (Houdret and Bonnet, 2016). Whether the solution is to bring in more water or to improve farm-level efficiency, controlling expansion is the key issue to consider.

All these elements leave little doubt that focusing on plot level efficiency is self deceiving.[21] The mistake of focusing on plot level efficiency only has a long history. It has been legitimized by countless references to "inadequate demand management, as reflected in *losses* of over 60% of irrigation water" (World Bank, 1995; emphasis added). Potential water savings in the Mediterranean have been estimated by the Plan Bleu in the late 1990s at almost a quarter of the total water demand by 2025, with two thirds of them to be realized in the agricultural sector, and this has been taken as a regional target objective (Plan Bleu, 2012). This target is supposed to be achieved by raising average plot level irrigation efficiency to 80%, reducing conveyance losses down to 10%, raising distribution efficiency in the domestic sector to 75%, and the rate of recycling in the industrial sector to 50%. These targets[22] make little sense because they are based, again, on a consideration of efficiency at the user level[23], without considering that a large

[18] Arguably this depends on local conditions. When the aquifer is very deep there is the perception that water does not really go back to the aquifer. This was the case in the Highlands of Jordan (where the water table can be 100 m deep or more). Although it is possible that a fraction of the water percolating is taken up by evapotranspiration (capillarity and phreatophytes) studies on water quality have identified a high level of nitrates near agricultural wells (JICA, 2001), pointing to a significant return flow to the aquifer.

[19] There is currently no talk in Morocco of reducing water diversions for environmental purposes.

[20] Indeed the Ministry of Agriculture well recognizes that with the exception of the Loukkos and the Gharb, where 100,000 ha are still to be developed, no reallocation or extension can be envisaged since all schemes already face large deficits that need to be compensated for (MAPM, 2007b).

[21] Official documents often state that "it is at the level of the plot that lies the main potential source of water saving in irrigation systems" (El Gueddari and Arrifi, 2009), a costly misconception that appears in the early 2000s (see El Gueddari, 2004).

[22] Water savings observed between 1995 and 2010 in the Mediterranean have been estimated by Blinda (2012), based on declarations from Mediterranean states, at 22 Bm3, against an initial provision of 56 Bm3 at this date (and a final target of 67 Bm3 in 2015), who believes therefore that 40% of losses have already been recovered…

[23] Plan Bleu's (2008) note on the improvement of water use efficiency in Morocco sticks to conventional use-based efficiency indicators.

proportion of river basins in the Mediterranean are under stress (or 'closed'), and therefore return flows are in general already appropriated.

More recent analyses have raised doubt about this approach. GWP (2012) found this to be an "optimistic perspective" but despite a short caveat signaling that "most of the 'losses' infiltrating the soil and finding their way to aquifers are streams which can be reused downstream", the report cites at length the Plan Bleu's numbers and targets, implicitly lending them credit. Chohin-Kuper et al.'s (2014), in their report to Plan Bleu, undo this confusion and acknowledge that "results in terms of improvement of efficiency [between gravity irrigation and drip] are very mixed", because drip technology is not well handled and mastered, intensification or expansion at the farm level most often result in an increase in water demand, and because losses are generally found to be reused at a larger scale, singling out facts that are emphasized in this report.

At this point, a very striking parallel can be made between the situations observed in Spain and Morocco. While Morocco developed its National Plan for the development of microirrigation in 2002, and the PNEEI later in 2007, Spain launched its National Irrigation Plan in 2001 and its "Shock Plan" (*Plano de Choque*) for micro-irrigation in 2006. With an expected budget of €3.7 billion, the PNEEI compares with the €7.3 billion of the two Spanish plans cumulated (Lopez-Gunn et al., 2012). Both the *Plano de Choque* and the PNEEI had level of subsidies of 60% (later 80-100% for the PMV), while water-savings targets were 2.5 Bm3 and 3.2 Bm3 for Morocco and Spain, respectively. Their Mediterranean physical environments and types of agricultural production are also very similar, and it is no surprise that the same outcomes are now surfacing. In Spain, WWF, which had long taken at face value the promises of drip irrigation and advocated it worldwide[24], has now awaken to the bleak reality that the billions of euro invested in the name of water savings have often promoted exactly the opposite (WWF/Adena, 2015).

A further observation that applies to both Spain and Morocco is that the overall hydrologic reality is obscured by the benefits generated in terms of increased productivity and farm incomes, and diversification to cash crops (as described earlier in section 3.3).

The overall picture that emerges from these observations includes two crucial elements: from a positive perspective, in the large majority of cases drip irrigation does deliver in terms of land productivity (yield), total production and farm income. Whether by adopting cash crops or through intensification or expansion, farmers' net benefits are increased, as is production at the national level. However, the downside of the process is that these private benefits come at a huge environmental and social cost: the depletion (or consumption through evapotranspiration) of more water. Simple arithmetic has it that in many major irrigation areas the massive shift to drip irrigation has been accompanied by a more pronounced deficit of aquifers, the very opposite of the 'savings' that were foreseen based on the simplistic projection from current and expected plot-level 'efficiency' ratios (50% and 90%). Contrary to common wisdom, which sees micro-irrigation as a water-saving technology, the implementation of drip results in greater groundwater *depletion*[25] (or, at best, is neutral). The eye-catching claim that the PMV can lead to

[24] See announced savings of up to 80% for irrigation of cotton in India (WWF, 2003) or its efforts to introduce drip irrigation to farmers in Turkey, with reports of improvements in plot level efficiency only (WWF, 2009).

[25] Oddly enough, Jack Keller, an American water expert who has contributed to the understanding of the scale dependency of the notion of water-use efficiency (see Keller et al., 1998) was part of the team of experts consulted by the Monitor Group (2008), which sketched out the new National Water Strategy. He seems to have failed to appreciate the extravagance of the water savings plan, although it is also possible that his observations have been partly ignored or watered down: he is reported, under the heading 'A rigorous water demand management is necessary', to have remarked that "the real water savings derived from the installation of efficient irrigation techniques vary according to the water profile of the area converted to drip irrigation, because return flows to the aquifers decrease with drip irrigation".

"triple the production with half the water" (L'Economiste, 2016) is based on confusion between plot-level and system-level efficiency. But this is not all.

1.2 The *Plan Maroc Vert* and incentives to expand groundwater-based irrigation

Further to the launch of the PMV, conceived as an overarching program, other ongoing activities from the Ministry of agriculture have been subsumed into the PMV (Belghiti, 2010). This concerned in particular the PNEEI which, as mentioned earlier, set out to enhance the level of support for the conversion to drip irrigation to 100%, to offset any reluctance from farmers due to financial considerations. But this subsidy level has generated a situation where irrigation equipment salesmen and design companies enter into direct contact with farmers or water user associations to propose turnkey projects in which they take care not only of the implementation of the project, but also of the administrative procedure to receive the subsidies and obtain drilling authorizations (BRLi and AgroConcept, 2012). For larger farmers only eligible to a 80% level of subsidies, techniques of overbilling have been developed to provide projects at no cost to farmers (Tanouti et al., 2016).

There remained a number of constraints to the development of such projects, however. These include the need to show a legal land title as well as a certificate that the well to be used is registered and groundwater abstraction authorized. The government has also undertaken registration processes for all existing wells, up to 2015. Few farmers were interested in going through the administrative process to register their wells until it became a condition for accessing the generous subsidies of the PMV (see section 4.3 for more details on well registration).

In the 2010s the windfall subsidies of the PMV caused the number of applications to soar and the authorizations for the abstraction of groundwater were initially granted with few exceptions. Following the closure of registration programs, however, the ABHs – as managers of the resource – became unwilling to grant such authorizations, as they were clearly contributing to the development of new wells and worsening over-abstraction. The contradiction with the impetus of the PMV, geared towards increasing production and productivity, was 'solved' by offering loopholes to farmers so that drip irrigation projects and their subsidies could go ahead. In the Saïss it became possible to apply for subsidies, without formally going through the ABH, merely by producing an affidavit that the plot (and the same area) was already being irrigated by the well (Del Vecchio, 2013). Referring to a promise to boost the responsiveness of the administration, others claim that if the administration has not answered a request (for a drilling authorization) within 60 days, it ought to be considered as granted (ibid.)[26]. A lack of enforcement is also observed with regard to the theoretical well depth limitation (100 m), which is frequently ignored (ibid.). In the Haouz farmers must display an administrative document showing they have *initiated* the procedure to register their well with the ORMVA (Tanouti et al., 2016). This of course has opened the door to the drilling of new wells, subsequently declared as 'old' (pre-2009).

Fieldwork also provided numerous testimonies indicating that illegal, but also legal, well drilling is still possible either through personal arrangements with local authorities, or through the intervention of influential people in the government or political system. There is clear evidence of investors using influence to acquire well authorizations for developing plantations on (collective tribal) land leased by the Ministry of interior, on the public domain of the

[26] This may be a self-serving interpretation of the '*Décret n°2-00-474 du 14 novembre 2000 fixant la procédure de reconnaissance de droits acquis sur le domaine public hydraulique*', which states that procedures to recognize 'acquired rights' (prior use) should not exceed 60 days.

SODEA/SOGETA[27] parceled out to investors, or on land acquired on the market. Near Marrakech, for example, three consortia of investors have leased a total of 700 ha of the agrarian reform land that had been unallocated and left fallow. Satellite images (see Appendix) reveal several recent developments based on groundwater that clearly compound the deficit status of the aquifer. On top of that, abstraction is also increased by the expansion of private villas into land that was previously fallow, rain fed or poorly irrigated, which drill their own wells to irrigate their gardens (~2000 ha around Marrakech, see Appendix).

In the Saïss Plain, Fofack (2012) found that farmers could sometimes go through either the *caïdat*, who can mediate the request through the ABH, or through the sellers of drip irrigation systems, who can take care of the application process and possible arrangements with the Ministry of Agriculture. In other words, parallel lines of authority through the *wilaya* and *caïdats* (Ministry of Interior), the Ministry of agriculture, or otherwise, undermine, if not nullify, the responsibility of the ABH for sustainable water use. They also belie the official window-dressing discourses that emphasize the integration of sectoral policies and objectives.

To qualify for PMV subsidies it is obligatory to install water meters. Yet field visits are limited and violations usually only result in a letter from the administration ordering the farmer to install a meter. If the conditions of the loan are not met, the state has the right to recover the subsidies allocated within five years. But no follow-up is in order (BRLi and Agroconcept, 2013).

The intricacy of Moroccan land tenure has often been seen as an obstacle to development (World Bank, 2008), as only 76% of the agricultural land is considered as *melk* (private properties), of which only 15% is formally registered[28]. In 2005, a new law (the so-called '*de la main levée*') allowed members of agrarian reform cooperatives to privatize their plot of land, and trade it on the land market (Valette et al., 2013). This land is bought by investors who have speculative and/or productive objectives, either for agriculture or urban development (e.g. land bought by the land developer 'Doha' south of Marrakech; see Valette et al., 2013 for the case of Meknes). Collective lands under customary ownership (*terres collectives*) have also long been coveted by investors to develop new tree plantations, such as in the Haouz, the Souss (BRLi and Agroconcept, 2013) or eastern oases (date palm trees in Boudnib[29]). These lands are attributed by and under the control of the Ministry of Interior, out of the control of line ministries. They too face a process of *melkisation*, with 300,000 ha of collective land about to be registered ('for free') in the name of right holders (Belghazi, 2016).[30] Recently a consultant bid was announced to take care of the melkisation of 46,000 ha in the Gharb.[31] 85,000 ha of land under *habous* status (*waqf*), managed by the Ministry of Habous, as well as the 300,000 ha of *guich* land, are also under pressure to be privatized (maroc.ma, 2015).

In sum, the PMV has both removed constraints to accessing land and provided loopholes to circumvent the constraints to, or the prohibition of, well drilling in overexploited areas by not requesting a formal authorization of well drilling or use, while ABHs have willingly or not accepted to regularize recently drilled wells presented as old wells, and been compelled to deliver authorizations for investors developing new irrigated land based on groundwater. How large is the expansion planned by the PMV? The Monitor Group (2008) provides an indirect

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[27] Public bodies in charge of managing land recovered from colons after independence (and not redistributed).

[28] On land tenure in Morocco see Bouderbala, 1999; World Bank, 2008; Mahdi, 2014; Daoudi, 2011.

[29] www.usinenouvelle.com/article/l-or-brun-du-desert-ou-quand-la-datte-du-maroc-se-met-a-l-heure-de-l-agri-business.N227927

[30] It is no coincidence that the information given by this article has been advertised on the facebook page of the '*Fédération Marocaine des Associations des Professionnels de l'Irrigation*'.

[31] http://appel-d-offre.dgmarket.com/tenders/np-notice.do?noticeId=13421894

answer by considering an additional water demand of 1 Bm3. As an official of the Ministry of agriculture put it, referring to the PMV and the overexploitation of the Saïss Plain aquifer, "we are subsidizing a disaster in the making" (quoted by Del Vecchio [2013]).

3. Water savings policies: accompanying measures and discourses

The preceding section has drawn attention to how uncontrolled and even incentivized expansion of groundwater-based agriculture, as well as a highly subsidized process of intensification, are resulting in more water (most particularly groundwater) being depleted. We examine here how the official discourse reflects some of these contradictions and whether and how such negative impacts were identified or anticipated.

1.3 Passing qualifications

The main 70 page official document of the PNEEI has only two paragraphs stating that water efficiency is scale sensitive and that losses at the plot level might not be real 'losses' when seen at the scale of the river basin. This passing caveat is then totally forgotten and the remainder of the document builds upon the statement "that it is at the level of the plot that water savings must be sought" (MAPM, 2007a).[32] The report estimates total expected water savings at 826 Mm3/year. The first 514 Mm3/year should be recovered based on the improvement of conveyance and plot level irrigation efficiencies (for large-scale irrigation). But this volume will *not*, according to the report, be reallocated to another use and will merely improve the effective supply to the crops, presumably (although this is not clearly spelled out in the report) merely substituting groundwater for surface water (and therefore generating benefits in terms of reduced costs and better water quality, while keeping the net balance of the aquifer untouched). The second portion of water savings (312 Mm3/year) is expected in groundwater-based private irrigation. Here, again, if ET is unchanged then the *net* abstraction of groundwater will also be unchanged and no real savings will be forthcoming…

Interestingly, the risk of an increase in net water consumption due to expansion or intensification is not mentioned in the main project document but does appear in the '*Note de synthèse*', an abridged version (MAPM, 2007b). It identifies natural, institutional, technical, financial and commercial risks associated with the PNEEI, and those in the technical field are stated to be: "expansion of irrigated areas, the increase in the overall consumption at farm level following excessive intensification, or a response by farmers below expectations" (MAPM, 2007b). Despite assurances that "mitigation of these risks is planned under the program" (ibid.) there is no indication of the kind of measures that could achieve this. Beyond the specifics on how much water will be saved, emphasis is eventually placed on agricultural transformations:

> The PNEEI is foremost, of course, a program aiming to save water in irrigation (the primary consumer of water in the country), but it also aims to inject some dynamism into the agricultural sector through the transformation of its irrigated subsector. The realization of the program will lead to a radical change not only in irrigation practices but of irrigated agriculture itself, and will

[32] In general policy documents issued at the same time, the question of scale-sensitivity has just disappeared. To take only one example, the 'Prospective Maroc 2030' document only remembers that "In the irrigated sector, the shift towards an efficient and water-saving management would allow a significant increase, maybe in the order of 80% between now and 2030, in the added value generated by 1 m³ of mobilized water. Many recent examples show that water saving irrigation technologies can allow physical water savings of 20 and sometimes 50%" (HCP, 2007).

> enhance the development of rural areas. This irrigated agriculture will be modernized, will invest increasingly and will generate better incomes [emphasis added] (MAPM, 2007a)[33].

The "risks" associated with a possible increase of per ha water consumption or continued expansion, or the scale-sensitivity of the concept of efficiency, are generally well understood by Moroccan engineers and experts[34]: this is apparent from passing acknowledgements in many reports, debates in workshops and conferences[35], as well as personal discussions. On the other hand, the same reports include many contradictory statements, and the objective of achieving (plot-level) water savings and developing drip irrigation eventually prevails.

1.4 Stated socio-economic and environmental impacts

The 2003 law on environmental impact assessments, "a key instrument of environmental risk prevention", has an appendix which specifies which kind of activity is concerned by the law, and this list does not include irrigation projects (FAO, 2015). However several studies concerning the environmental impacts of the PNEEI have been carried out.

FAO first designed a social and environmental management plan, as part of the Support program to the PNEEI funded by the African Development Bank. The project document (FAO, 2009) identifies a number of risks, including the reduction of the recharge of aquifers by drainage water, the increase in the concentration of salts and chemicals due to a reduction in leaching, or even "the risk of favoring production to the detriment of the conservation and protection of resources". Overall, however, "the results of the environmental assessment confirmed that the impacts on the environment of the project activities are largely positive", and that "*no major negative impact has been identified*" (ibid.).

The issue of reduced aquifer recharge is addressed later on through three sentences:

> Water saving generated by micro-irrigation must be qualified by the impact of the reduction in groundwater recharge through the infiltration of irrigation water. Mitigating this impact requires abstraction from wells to be restrained. Indeed, the number of groundwater abstraction points has increased significantly over the past two decades. This measure must be accompanied by effective implementation of the licensing procedure for the realization of new boreholes or wells (FAO, 2009).

Somewhat contradictorily, in the list of the program's objectives the "fight against water losses" ("large quantities of water allocated to agriculture are lost") is paralleled with another bullet point on "the fight against the overexploitation of aquifers" and the expectation that the PNEEI will also "eliminate the risk of seawater intrusion in coastal aquifers" (MAPM, 2007a), which is hard to understand if recharge of the aquifer is reduced. In any case reducing aquifer drawdown and sea water intrusion means going beyond the mere substitution of irrigation water for groundwater, which leaves the net balance unchanged (assuming, conservatively, that evapotranspiration (ET) remains the same); it means reducing the irrigated area.

How can groundwater abstraction be restrained? The parallel measures mentioned for a "rational management of groundwater resources" include a) an exhaustive inventory of wells, to be complemented by a survey on actual abstraction, b) awareness raising campaigns about the risks associated with overexploitation, c) the establishment of 'aquifer contracts' by the RBOs,

[33] All media channels echo these quantitative targets, e.g.: "increase in irrigation efficiency from 50 to 90%, enhancing irrigation water productivity from 2,3 to 5,5 Dirham/m3, an increase in the value of production per hectare from 19,000 DH to 42,000 DH per year, in addition to an improvement in farmer income" (SEMIDE, 2012).

[34] Sraïri (2015), for example, "recognizes that the shift from gravity irrigation to drip does not always result in a decrease in water consumption, when it is not paralleled with a regulation of the area irrigated and abstraction".

[35] e.g. in the AFEID meeting in November 2014.

and d) the installation of meters for all groundwater users, "a very tricky but totally inescapable measure to be implemented" (MAPM, 2007a)(all this, of course, is easier said than done and these measures will be further discussed in section 4).

How can irrigation practices and farmers decisions be monitored in order to make sure that the conversion to drip irrigation is associated with real water savings? The question cannot be fully eluded by the development banks[36], which have environmental guidelines dictating that projects should not result in environmental degradation. The FAO has been entrusted with the development of a monitoring and evaluation program and has proposed a number of indicators (FAO, 2011). In addition to relevant indicators on land and water productivities, the FAO proposes to monitor the volume of groundwater abstracted which should be determined by an estimation of the volumes extracted by a sample of farmers (it is not mentioned how this volume would be estimated, nor that farmers do not have meters). Another indicator would be the "volume of groundwater consumed" which would be estimated as the amount of crop evapotranspiration (estimated by remote sensing) not met by the surface water applied. Here also it is not mentioned that the uncertainty on both actual ET estimated by this method and on the fraction of the surface water applied (itself not accurately known) that is transformed into evapotranspiration is much higher than the changes that are supposed to be evidenced and monitored on a yearly basis. From a technical point of view it can be safely stated that this approach will fall short of providing a satisfactory 'monitoring' of the water balance.

In 2015, FAO also conducted the environmental impact assessment of the Project of modernization of large scale irrigation, that is part of the PNEEI, in order to make sure that the project is consistent with the laws and regulation in Morocco as well as with safeguard policies of the World Bank (FAO, 2015). Its report lists the environmental impacts associated with the implementation and ensuing exploitation phases, as well as expected benefits. Expected negative impacts of the exploitation phase include "reduction in the recharge of aquifers by return flows due to the reduction of the volume of water which previously percolated to the aquifer", accumulation of salts or chemicals in the soil due to reduced leaching, or generation of plastic garbage when renewing the lines of drippers. These impacts are to be mitigated by "repeated leaching after harvest" and "rational fertigation practices", but no mention is made of how to tackle the issue of reduced recharge (FAO, 2015).

These impacts (to be 'mitigated') are contrasted with a long list of environmental and socio-economic benefits, including "Conservation of water resources through the rationalization of the use of water for irrigation and the reduction of water losses at the plot level, in irrigation systems and conveyance channels", and benefits linked to better agricultural practices, yields and income, improved quality of the aquifer, reduced water-logging risk, lower water bills, or decrease in mosquito breeding sites (FAO, 2015).

Although a full discussion of these technical aspects lies beyond the scope of this report, it must be noted that the improvements of the quality of groundwater because of reduced leaching is debatable. The type of agriculture that comes with drip irrigation is generally much more intensive, with a higher use of pesticide and fertilizers (FAO, 2001; Keddal and N'dri 2007). Drip also better supplies the plant but the salt accumulates near the root zone. These elements will be leached, precisely through the leaching practices that are recommended as part of mitigation measures, and their *concentration* in aquifers and drains/rivers will be *higher* because of the reduced return flow and the enhanced use of agrochemicals. Likewise, whether energy savings[37]

[36] In particular the World Bank, in its financing of the PMV.

[37] Energy used for pressurized irrigation and corresponding subsidies are now coming under scrutiny (Doukkali and Lejars, 2015).

will be forthcoming will depend on the situation: this will be the case for example in the N'fis area, near Marrakech, where groundwater pumping will be partly substituted by water pressurized by gravity. But at the plot level gravity irrigation will also be replaced by a pumping operation (from the farm reservoir to the crop; like in the Doukkala, where FAO (2012) found a 130% increase in water costs), or a second pumping in groundwater-based gravity irrigation, that will add to the cost of pumping at the level of the well.[38]

The document refers to the possible drop of the water table due to a reduction of the return flow from irrigation but indicates that this effect will be *compensated* by the reduction in pumping from the aquifer. This is an acknowledgment of the fact that modernization will indeed (in fact at best) be neutral with regard to aquifer overexploitation (but the intensification and expansion associated with it and described earlier will actually make it worse).

Other risks, not analyzed in this report, are linked to the financial vulnerability of farmers having been lured by 100% subsidies into a more capital-intensive agriculture, and "the principal risk [of] poor performance (whether technical or financial) of agriculture converted to micro-irrigation, with farmers blaming the irrigation technology itself, and as is the case in many countries, returning to their traditional irrigation techniques" (MAPM, 2007b). It would be crucial to monitor, in the coming years, the small farmers who have adopted drip irrigation, and also to document possible social differentiation (Ameur et al., 2017).

1.5 Conflating water savings and water productivity

"Despite the efforts deployed to better mobilize water resources, Morocco is facing a looming crisis" (MAPM, 2007b). Regions in the center and the South of the country "already face pronounced water deficits that are expected to be witnessed in other regions. In the long run, the whole country is to face a situation of water scarcity" (ibid.). Most of the PNEEI is justified by a dreary situation in terms of present and future water status, but most of the promises are expressed in terms of improved land and water productivity, rural incomes or competitiveness.

Although very prominent in media releases, the question of water savings brought about by the PNEEI/PMV is often subsumed within the wider question of modernization of agriculture towards higher land and water productivity. Many examples of subtle discursive shifts can be noted. In a note published in April 2007 titled "Agriculture 2030", the '*Haut Commissariat au Plan*' (HCP) wrote that "the transition to a water-conserving and effective management of water would significantly increase, by 2030, the added value generated per m3 of water used (in the order of 80%)" (MAPM, 2007b), but the latter benefit is in reality not linked to former hypothetical water savings.

Belghiti (2009) goes on to stress that "the real source of water savings in situations of water stress lies at the level of improving water productivity and the value-added generated. In other words, the objective is to produce more wealth (agricultural production, added-value, jobs,…) out of each cubic meter". And finally El Alaoui (2006) clarifies the matter by stressing that "in irrigated agriculture, and contrary to what one might think, a thrifty water management (*gestion économe*) *does not aim at a reduction in the consumption of water in itself* but rather at increasing the added-value (*valorisation*) of the use of water" (emphasis added).

In other words, the expected benefit of water savings frequently finds itself conflated with those -much less controversial- of agricultural intensification and increased land and water productivity, finding itself implicitly validated.

[38] The increase in the cost of energy associated with the shift to drip irrigation is the most salient issue emphasized in the literature on drip irrigation in Spain. See, for example, Fernández García et al. (2014) and González-Cebollada (2015).

4. Water demand policies in perspective: a wake-up call

While the problems with the water-saving claims of the PNEEI/PMV described in the preceding section of this report had been identified, it is striking to note that such crucial issues were paid only cursory attention even by environmental impact assessment studies. In this section, having examined in detail the impact of disseminating micro-irrigation (see Section 1.1), we briefly examine the three other main measures put forward by the government to address water scarcity and control groundwater over-abstraction, namely a) water pricing, b) registration and prohibition measures, and finally c) aquifer co-management ('aquifer contract'), and put the Moroccan situation in perspective using the international literature.

1.6 Water pricing

Irrigation water pricing has long been advocated by the World Bank and mainstream organizations, based on the idea that "due to low water prices which do not even capture the full private costs, agriculture is an extremely inefficient and wasteful user of water" (Shetty, 2006). To cope with water scarcity, "full recovery of the cost of irrigation water and the integrated management of the resource would lead to significant gains in efficiency and encourage a shift to crops requiring less water" (OED, 1998). Intensely promoted in the 1990s[39], the idea was shifted to the backburner in the late 2000s[40], partly due to the recognition that the field of irrigation, especially large-scale irrigation, presented key differences from the urban water or energy sectors, where pricing tools have well documented applications (see Cornish et al. 2004; Hellegers and Perry, 2004; Molle, 2009; and Molle and Berkoff, 2007 for a full analysis of the reasons for the failure to achieve irrigation water savings through pricing).

ORMVAs cover barely half of their irrigation needs, meaning there is therefore no 'wastage', from which one could expect farmers to reduce their 'demand'. The marginal value of this water in terms of production is far higher than its cost to the farmer, which would still be the case even if the full operation and maintenance (O&M) costs were recovered from farmers[41]. It is well recognized that overly high prices would also push farmers to shift to groundwater, where aquifers are not too deep (Monitor Group, 2008), as is observed in the Loukkos, for example. Indeed, many already do so not to reduce costs (they actually increase) but because groundwater is available on-demand and escapes the rigidity of irrigation rotations.

Charging for irrigation water remains an important objective in terms of O&M cost recovery and the financial sustainability of ORMVAs. Morocco was forced to raise its rate of cost recovery as part of the structural adjustment measures taken in the 1980s. The World Bank developed a 'Bulk water pricing study' as part of its 1998-2004 'Morocco Water Resources Management Project' and tariffs were raised again during the 1997-2006 period. The recognition that "with the establishments of ABHs, the main part of their budget has to come from water users" (World Bank, 2009) also enhanced the necessity to recover costs from users. Water pricing has

[39] The Bank's Morocco water sector review of 1995 well reflects the flamboyant years of textbook economics following the 1993 Water Policy paper. The review promotes the idea of full cost recovery and water rights trading, and notes that "the opportunity cost of water use is becoming increasingly important, particularly in deficit basins, and the pricing of water at its opportunity cost should be introduced to the extent possible into the decision making process".

[40] Comparison between the 1993 and the 2003 World Bank's water Policy Papers clearly reflects these changes.

[41] The idea of charging much beyond this level in order to constrain demand is precisely the idea that has been proved to be politically unfeasible worldwide. Studies have invariably found that to affect demand prices would have to be very high, with substantial impacts on incomes.

therefore been promoted primarily for financial reasons[42]. In any case, raising prices sufficiently to cover O&M costs has proven to be problematic. For Doukkali (2005) "the inability to complete water-pricing reforms clearly suggests how political costs have overshadowed the real socio-economic and resource costs".

Yet water pricing has resurfaced, however timidly[43], as one of the measures listed to help combat the overexploitation of aquifers. A very limited percentage of farms currently pay the official fee (established at 0.02 DH/m^3) for the groundwater they abstract. The Monitor Group (2008) considers that water pricing is a 'lever' with a "high level of influence" on demand. It is therefore proposing an increase in the price of groundwater as well as the establishment of a premium (higher) price for water abstracted in overexploited aquifers. This is implicitly based on the idea that administered prices (that is, prices set by the administration for the use of the resource) could be high enough to encourage lower abstraction. A recent worldwide review on groundwater governance, however, found no evidence that in any country in the world this had ever been successfully implemented (Molle and Closas, 2017). To clarify, administered pricing is different from instances where the cost of energy for abstracting water may have an influence on how much water farmers abstract and what crops they grow. Energy cost is frequently maintained at a low level through state subsidies and these subsidies can be modified to influence demand (see elements for Morocco in Doukkali and Lejars, 2015). There are several examples (Spain, Syria, India, Morocco, etc.) of farmers reverting to rain-fed agriculture or abandoning fields altogether when costs increase, either because of dropping water tables or increases in fuel/electricity costs (or a combination of both).

In summary, by putting upfront administered prices as a water demand management tool, policies promote a measure that is doomed to failure, and remain silent about the more politically sensitive issue of energy subsidies (very recently cancelled on diesel), notably about how domestic gas (that came to be cheaper than diesel) is now widely used for groundwater pumping.[44] By envisioning a volumetric pricing system, policy-makers also make it conditional upon the identification of existing wells and the thorny prerequisite that the use of each farmer should be volumetrically known.

1.7 Well inventory and registration, and water meters

Charging farmers, or limiting their use of groundwater by other means, requires information on their wells and farming activities. All countries with a large scattering of independent, small farmers face the difficulty of creating an exhaustive inventory of groundwater abstraction points. Most countries have compulsory registration and administrative processes for the authorization

[42] It is tempting to establish a parallel between the promotion of water pricing and that of drip irrigation: just as drip irrigation has been shown above to be promoted based on its impact on water savings *and* land/water productivity, irrigation water pricing has been proposed based on its alleged impact on water savings *and* financial sustainability. In both cases the two arguments are discursively confused – the former offering an additional justification to the latter.

[43] The PNEEI (MAPM, 2007a) only refers to the water pricing 'lever' as one of the tools of demand management but does not develop its application as part of the plan. The National Water Strategy merely mentions the "adoption of a water pricing system based on volumetric metering" (Royaume du Maroc, 2011), while the Ministry of water (DRPE, 2014), in a recent report on its efforts towards establishing 'aquifer contracts', listed 'water tariffs specific to groundwater use', as one of the measures envisaged.

[44] Strikingly, the Ministry of agriculture and the Ministry of energy not only do not address the issue of the subsidies that go to groundwater pumping, but they have also set up a 40 million euro program to subsidize solar energy for farmers; it is not known whether the Ministry of water is supportive of this plan, which is likely to be detrimental to groundwater conservation. This has been casually observed by Tanouti and Molle (fieldwork) in the Haouz, near Marrakesh, where according to the ORMVAH (personal communication) around 30 farms have already adopted 'solar irrigation' (www.agriculture.gov.ma/pages/actualites/le-programme-national-de-pompage-solaire-un-projet-rentable-pour-letat-et-les-agriculteurs)

of drilling (and using) wells (Molle and Closas, 2017). A common problem they face is with those wells drilled prior to the introduction of compulsory permits. The lax enforcement of a process that is generally costly and burdensome for users means it can also take several years for governments to discover the many wells drilled after this date that were never registered and to toughen their measures.

In Morocco a decree issued in 1997 stated that water withdrawal points established before the enactment of the 1995 law should be declared to the ABHs within one year of its publication. In 2009 a new decree gave another period of three years for the regularization of wells drilled prior to the date of this decree (i.e. January 2009), opening the way for the regularization of wells dug illegally over the preceding fifteen years. When this second legalization period elapsed in February 2012, few users or well owners had shown up and many of those who did came in during the final days and saturated the system (BRLi and Agroconcept, 2013; L'Economiste, 2015). As a result the deadline was extended for a third time (until October 2015), after which date no further extension would be granted and violators would face penalties of up to 2000 DH. All wells drilled prior to April 2009 must be registered. Wells drilled after this date are considered illegal unless their owners have requested and received authorization (ibid.). These successive steps convey the message to farmers that registering is not so important and that more time will eventually be given to them to legalize their wells. The lack of interest shown by farmers can be explained by the burdensome procedure and having – in theory – to install a meter at their own expense (the price of which varies between 1500 and 2000 DH for small farms and reaches 20,000 DH for large farms). In addition the owner of the well must declare the consumption once a year and pay a water bill based on the rate of 0.02 DH/m^3 (L'Economiste, 2015).

There is no reliable inventory of wells in Morocco at present. Their total number is put at roughly 100,000 (Kuper et al., 2016), most probably an understatement. In the Souss-Massa-Draâ basin the authorization procedure is widely disregarded (L'Economiste, 2014a). Of an estimated 17,000 existing wells only 2,000 have been authorized, and a network of small drilling companies is working covertly to meet the demand generated by water shortages and drought (ibid.). The ABH of Tensift has inventoried (circa 2010) 10,700 wells, of which it estimates 31% to be illegal, making a total of around 14,000 wells in the Haouz; but according to one official the real number is more believed to be around 25,000. In addition it is not clear how many of these wells are seeing their capacity reduced or cancelled due to dropping water tables.

It can therefore be concluded that the situation with regard to wells is far from under control. As long as the percentage of illegal wells is so high it is unrealistic to envisage controlling the amount of water abstracted in the wells that are known to the administration, all the more so since the monitoring of drilling is still slack and new wells are being dug every day. As one magazine observes, "the drop in the cost of well drilling, pumping and irrigation equipment, in addition to subsidies allocated by the state, have encouraged the farmers to invest in wells", and with the lack of rain in 2015-2016 "those in the well-drilling and irrigation-equipment sectors are witnessing the growth with satisfaction" (Finances Hebdo, 2016). At the same time, however, many other wells are drying up and being abandoned.

If the experience with the registering of wells and installation of meters in the MENA region is anything to go by[45], it is safe to assume that Morocco is decades away from being in a position to

[45] The experience of Jordan, for example, which only has 3200 working wells and where the government has shown exceptional resolve in the past five to six years to control illegal drilling and assess volumetric water use for each well (see Al Naber and Molle, 2017), demonstrates the difficulty of the task in a country where the political will to control well drilling and abstraction is still lacking. No country in the region has been able to inventory its wells, with the exception of some Gulf countries (see Closas and Molle, 2016).

control (let alone tax) water abstraction at the well level. Calls by the Economic, Social and Environmental Council (CESE, 2014) for the "installation of water meters on all tubewells of small, medium and large farms and combating illegal water abstraction for irrigation", or the intention of the PNEEI to install meters at all abstraction points[46], fail to grasp the difficulty of the task and, at this stage, are tantamount to wishful thinking.

Control of illegal drilling appears to be the central challenge. As emphasized by the Ministry itself, the overexploitation of groundwater resources will continue "as long as clear procedures for their exploration and efficient water police are not in place" (MAPM, 2007a). The CESE (2014) calls for "the strengthening of the powers of the water police, in terms of means and ability to sanction, as well as the establishment of effective and efficient coordination with the other oversight bodies operating in the field of water (environmental inspectors, police and officials from *Eaux et Forêts*)". Meanwhile, the Monitor Group (2008) considers that "the water police and judiciary must be in a position to better enforce the law", since at present these responsibilities are diluted: "everyone is the water police and in the end nobody is" (ibid.). Del Vecchio (2013) cites an official from the Saïss who stated that the water police "only existed on paper", mirroring what was observed in the Haouz (fieldwork), where "control of abstractions does not exist; the water police is ineffective […] and the implementation of monitoring seems impossible due to the multitude of users" (ABHT and GIZ, 2011).

Although very weak and clearly insufficient, enforcement on the ground is not completely absent. For example, since the aquifer contract was signed in 2007 in the Souss (but remaining largely unimplemented) 76 drilling rigs have been seized and 900 violations have been prosecuted (illegal drilling is liable to a 20,000 DH penalty) (L'Economiste, 2014a). In the Bouregreg basin the water police registered and fined around 100 violations in 2014 and 20 rigs have been seized (ibid.). The Ministry of interior’s tight control through its local representatives (*caïds* and *moqaddem*) proves that stricter control could be exerted and points again to a lack of political will on the part of the Ministry.

1.8 Groundwater control and 'aquifer contracts'

At a meeting on the problem of groundwater overexploitation in Morocco the minister of agriculture emphasized that groundwater resources were "paramount for the agricultural development of many regions in Morocco", while the minister in charge of water stressed that the only option was to establish "a new mode of governance that encourages stakeholder participation and allows them to take responsibility within a negotiated contractual framework, that is, an aquifer contract" (quoted in Aujourd'hui le Maroc, 2014).

This last key measure to combat groundwater overexploitation, aquifer contracts, or '*contrats de nappe*', signals the influence of a solution that is being tested in France, notably in the Beauce region, south of Paris. The idea of aquifer contracts stems from the evidence that top-down groundwater governance, overly reliant on regulation and control measures, is not effective. The way forward is seen as the co-management of aquifers between the users and the administration. Although this is probably insufficient it is deemed necessary to involve all stakeholders in the design of shared solutions and collective rules. "Everyone recognizes that the water police, in conventional terms, based mainly on repression, has stalled" (MAPM, 2007b). The proposal made by ABHs to establish aquifer contracts is seen by the Ministry "as opportune and in need of being realized at the soonest" (ibid.).

[46] "A very delicate, but totally unavoidable, operation, because without water metering the reduction of abstraction is all too likely to remain a pious hope" (MAPM, 2007b).

Morocco's experience with *contrats de nappe* began in the region of the Souss-Massa, which produces around 60% of the country's citrus fruits and accounts for half of the country's agricultural exports (Houdret, 2012), and where groundwater represents 95% of the total water used. An agreement was signed in 2007 by the parties[47] involved in the *contrat de nappe* and by three large agricultural unions (vegetable and fruit exporters – the largest producers in the Souss-Massa region). It reflected the discussions that had taken place during the negotiations, including: freezing the expansion of irrigated areas for citrus and vegetables, the transformation of gravity irrigation to drip irrigation (funded by the region and also by fees levied on farmers' groundwater abstraction), increased fees for groundwater use, the completion of several surface water infrastructure projects by the state (22 small and 5 large dams), carrying out studies on the feasibility of irrigation with desalinated water in the Chtouka region and regularize 'illegal' wells.[48]

Eight years since the signing of the *contrat de nappe* the situation remains largely unchanged. Although awareness of the water situation has been raised, the contract has been undermined by a general *laisser-faire* attitude, the failure of the government to deliver on the supply augmentation projects, and a few good hydrologic years that have lessened the prevailing sense of urgency.

Nonetheless, around 2011 GIZ started supporting the ABH of Souss-Massa (ABHSM, 2011), Tensift (ABHT, 2011) and Sebou (GIZ, 2011) with overoptimistic planning of multi-stakeholder meetings expected to lead to an agreement on a convention after one year. These initiatives bumped into technical, institutional and political obstacles and did not come to fruition. In 2013 an inter-ministerial notification (*circulaire*), signed by the ministers of agriculture, interior and water, expressed political support and provided guidelines for the establishment of aquifer contracts.

In 2014 a national workshop on the management of groundwater resources again put aquifer contracts centre stage. The minister for water acknowledged the failure of the control of groundwater abstraction – a problem which neither the law nor the 2009 National Water Strategy could successfully address. The minister pointed to "a legal vacuum" with regard to aquifer contracts, and to some "reluctance among the partners of the department in charge". Yet at the workshop the Ministry presented a timetable of 15 major aquifer contracts, all slated to start before the end of 2016. The four components of these aquifer contracts, however, suggested a rather top-down approach, largely consisting of constraining measures: beside the need for improved "coordination between the actors involved in groundwater management" and technical monitoring of the aquifers, emphasis was placed on "strengthening the control system" (including the water police, self-control by water-user associations, involvement of the judiciary, registration of drilling companies) and the "limitation of pumping from aquifers" (water pricing, establishment of prohibition or safeguard zones, the obligation to use water-saving irrigation techniques when authorizations are granted, licensing of drilling companies). Recently the government has put the aquifer contract in the limelight again with a decision to have such contracts established in all major (later reduced to three) aquifers in Morocco by 2016 (L'Economiste, 2014b), in order to conform to a loan conditionality set up by the World Bank.

[47] Twenty institutional partners (including the governorate of the region, the River Basin Organization, local authorities, agricultural chambers, a federation of water users for agriculture, research institutes and water suppliers).

[48] The agreement also included enforcing rules and allowing the 'water police' to fulfill its mission, closing down wells (40 were envisaged in the convention), confiscating boring and drilling equipment (100 were aimed to be confiscated), the issuing of permits for drilling companies to operate, and the purchase of three cars for surveillance patrols.

The Master Plan (PDAIRE) for the Sebou basin mentions that a contractual approach (aquifer contracts) should be implemented, which would include in particular declaring the Saïss Plain as a safeguard zone, in conformity with the 1995 law, and a transfer of surface water. But the subsequent aquifer contract does not stipulate declaring the Saïss as a safeguard zone[49] and contains no provision for controlling the use of private wells and tubewells. This prompted Del Vecchio (2013) to comment that the aquifer contract is in reality "essentially a hydraulic and agricultural development policy characterized by strong interventionism by the Moroccan state". Indeed, it mainly restates the measures spelled out in the PDAIRE and does not seem to envisage coordination with or the participation of the users (ibid.).

Here again the international experience provides only a few examples where consultation with users was instrumental in the successful design of collectively agreed management rules. Situations with a few hundred or thousand users and more favorable climatic conditions, in countries from the north (e.g. Beauce, France; eastern La Mancha, Spain; Nebraska, USA; or Murray Darling, Australia), have few counterparts in the south (e.g. Bsissi, Tunisia, but with over a hundred users only, Frija et al., 2016), especially in dry countries where agriculture depends on groundwater and where the number of users exceeds 10,000 (Peru, Mexico, Tunisia, Iran, Pakistan, India, etc.) (see Molle and Closas, 2017). The mixed record of Morocco with participatory irrigation management and its political and managerial culture make it hard to believe that aquifer contracts could be successfully implemented. The jury is still out as to whether this is a promising way forward but relative the failure of the Souss-Massa contract, the first abortive attempts in the Tadla or Haouz and the current framing of the Saïss aquifer contract do not provide ground for much optimism.

In any case, as stressed by ABH officials, "the key to the success of the 'aquifer contract', is actually to stop the expansion of irrigation. The aquifer contract is both easy and complex: easy when you do the water accounting, but complex when it comes to identifying actions to ensure that the expansion of irrigated areas is stemmed" (Bouignane and Serrhini, 2015).

5. Squaring the circle: is "more with less, and better" possible?

1.9 A widening gap between discourses and reality on the ground

As mentioned in the introduction, Morocco can boast substantial achievements in the water sector and these are always underlined in the literature. The CESE (2014) stresses that Morocco is considered a "regional and continental model in terms of water management", with an "institutional governance model" and legislative framework considered as "exemplary", and a national water strategy that is "coherent and ambitious". According to Doukkali (2005), "from a historical perspective, the institutional reforms undertaken in Morocco, especially since the new law of 1995, are truly remarkable", while for El Alaoui (2006), "Morocco has, today, a unified legal and institutional system, complete, modern and consistent, to ensure, in view of the available water resources, a water supply that is in relative adequacy with the needs of the various sectors". The World Bank’s water sector review (1995) praised the commitment of the Moroccan government to the IWRM principles.

In the early 2000s the water strategy stressed "the necessity to integrate the diverse programs and policies on development, water and the environment, and to ensure their consistency" (ONDH, 2004). Later, in 2008, Morocco gave itself an "ambitious and innovative [updated] National Water Strategy […], with a roadmap for water management and precise quantitative

[49] It is interesting to note that the ABHS *does* support declaring the Saïss a safeguard zone (ABHS, 2006).

objectives up to 2030", that "has been harmonized and made consistent with that of agriculture documented in the PMV", according to the CESE (2014). Reportedly, "the two ministers [for agriculture and water] agreed on the need to implement a strong water resource management policy based on good governance" (Financenews, 2014). In other words, sectoral policies are integrated and harmonized, and aim at good governance and environmental sustainability.[50] Indeed, the new Moroccan constitution passed in 2011 declared that "sustainable development is considered a right for every citizen" (United Nations, 2014).

Behind conventional political window-dressing some concerns surface, however. The World Bank's 1995 review clearly showed little enthusiasm for the government's irrigation expansion policy, underlining that "the government's objectives of expanding irrigated areas, in the context of increasingly scarce water supplies, rising costs and less protected output prices, poses a severe challenge for irrigated agriculture", and that "the pushing out of the irrigation frontier to the limit of the resource available is expected to heighten the risk of seasonal or inter-annual shortfalls". Morocco's continued adherence to the longer-term strategy of "not one drop lost to the sea" (World Bank, 1995)[51] is now proving incompatible with environmental sustainability. Commenting on a publication documenting the National Debate on Water, the World Bank (2009) admits that its 2007 Water Sector Development Policy Loan reiterates the same reform objectives included in its 1998 WRMP project (securing water resources, safeguarding water quality, promoting efficient water use, limiting groundwater extraction and fighting erosion) and that "not much progress has been made".

The institutional architecture of the water sector is now being seen less positively. El Alaoui (2006) comments on the "compilation of fragmentary texts with a number of loopholes and inconsistencies, and [the] juxtaposition of sectoral institutions and missions [that] constitutes a heavy and costly technical-administrative apparatus". Likewise, Larabi (2012) points to "strategies with entangled objectives bedeviled by conflicts of jurisdiction" and a "legal arsenal similar to an armament without impact". The most salient critique, however, has come from an unexpected quarter. The CESE (2014) recently presented a long list of institutional dysfunctions within and between ministries, as well as at the higher advisory and coordination level. These included the absence of an operational regulatory body in the water sector (the inter-ministerial committee having been non-operational for years), failures to properly implement the 1995 Water Law (for example with regard to the polluter-pay principle, safeguard and prohibition zones on overexploited aquifers, sanctioning, and so on), insufficient coordination between departments concerned with water, ABHs lacking means, autonomy and independence and the *Conseil Supérieur de l'Eau et du Climat* (CSEC)[52] having an unclear role and jurisdiction.

It is becoming increasingly apparent that despite the participatory gloss put on the National Water Strategy, the decentralization of river-basin management, the elaboration of the PDAIREs and the planned aquifer contracts, these do not fundamentally alter a policy approach still largely based on state-planned supply management (such as PMV subsidies for well drilling, the remaining marginal dam sites to be developed, north-south transfer and desalination). The reality is a desiccation of the country gradually expanding northward and 'downward' (with 1

[50] World Bank (1995) observes that "The Under Secretariat for the Environment (SSE), initially under the MI, was upgraded in February 1995 into the Ministry of Environment (ME), thereby reflecting the commitment of the Moroccan authorities to a greater protection of the environment".

[51] "The initiation of the *Programme Nationale de l'Irrigation* (PNI) in 1967, with the primary objective of bringing a total of one million hectares under irrigation before the year 2000, was reinforced by a 1986 declaration of 'one dam per year'. Both goals are part of the Moroccan government's longer-term strategy of "not one drop lost to the sea" (World Bank, 1995).

[52] The National Water and Climate Council, "*internationally renowned* as providing a periodic focus for the review of sector priorities and master plans at the highest level", according to the World Bank (1995) (emphasis added).

Bm3 of groundwater depletion each year), aided by the continued and unchecked water-resource development by the government as well as individual farmers and investors.

Beyond the water sector itself, the worsening status of groundwater resources has much to do with the contradictory and antagonistic policies of the Ministry of agriculture. As explained in this report, support for agricultural intensification through drip irrigation and expansion by investors is threatening the water status of the country: although the development and 'professionalization' of Moroccan agriculture is a key national objective, this is done without a zoning that would indicate where it is compatible with the availability of water resources. According to one high-level official from the Ministry of agriculture (interviewed in 2015), the PMV follows the logic "first I boost production and then I solve the problems", while acknowledging that "we are not accurate enough with the evaluation of the resource".

The process of basin closure, whereby water resource development and use invariably comes to exceed available resources, is a generic process observed worldwide and is well described in the literature[53]. In Morocco it started in the Souss-Massa in the 1980s, moved north to the Tensift and the Oum er-Rbia and is now underway in the Sebou[54], where the remaining surplus water will soon be committed (100,000 ha expansion in the Gharb, irrigation development in the middle-Sebou, transfers to the Saïss Plain, increasing urban needs in Fès and Meknes, water transfers to Casablanca and further south, etc.). Although exhibiting a deficit of 840 Mm3/year (ABHOER, 2012), the Oum er-Rbia basin is strikingly *still* witnessing an expansion of irrigation, such as in Khenifra[55] and the Azemmour-Bir Jdid coastal area[56], not to mention the planned transfer of 118 Mm3 to Marrakech[57].

In closed basins where the final basin outflow is typically around 5-10% (as an order of magnitude) of the total runoff (much of which is either non-controllable floodwater or water that is very degraded in quality) – it is self-evident that very little or no water savings are possible since (almost) all the water is consumed. This is the situation in Moroccan basins, which have been found to have water use efficiencies of 90% (FAO, 2014). The main remaining opportunity is avoiding flows to sinks such as saline aquifers: this is certainly the case in the Doukkala, where the aquifer is very saline and groundwater use limited (Khyati, 2000), and where reducing percolation through drip irrigation is a clear gain. In other situations, a closed basin is a zero-sum game where a new source of evapotranspiration in a given location can only arise at the cost of an existing one. However, there may be a rationale to justify such a spatial shift: for *environmental reasons* it can be decided to shift the use of untreated wastewater in Marrakesh from small appropriators downstream of the city to golf courses (after treatment); for *economic reasons* it makes sense to shift the leakage of treated water in urban supply networks, reused by some well owners, to the expanding needs of the city (once this leakage has been reduced), to distribute irrigation water to the plant with higher efficiency rather than having to pump it again after it percolated, often with a degraded quality, or to limit return flows

[53] See Keller et al. (1998); Molden et al. (2001), Molle (2008), Molle and Wester (2009), Molle et al. (2010).

[54] The PDAIRE, under optimistic hypotheses and disregarding climate change, foresees an average discharge to the sea in 2030 of 500 Mm3, roughly 10% of average available resources in the basin.

[55] "During a visit to Khenifra as part of the PMV *Pilier II*, [the minister of agriculture] Aziz Akkhanouch announces that his department was examining a 3,000 hectare irrigation project that will use the waters of the Oum Errabia river" (HuffPost Maroc, 2016).

[56] "This project aims to convey 15 Mm3 per year of surface water from the Oum Er-Rbia river to safeguard an irrigation area of 3,200 ha used by over 600 farmers", according to the minister in charge of water (Albayane, 2013). The cost of this project is expected to be 13,000 US$/ha.

[57] A transfer of 118 Mm3/year from Massira dam to Marrakech is under construction (BAD, 2012), despite the fact that it is theoretically contingent upon the North-South transfer (which is yet to be funded and will, in all cases, take many year before reaching the Massira dam).

from irrigation areas if these get lost to a sink (such as the sea or a saline aquifer). For *equity reasons*, or established priorities (for example for domestic water), it may also be justifiable to reallocate water socially. Yet there is no doubt that positing that billions of m^3 can be 'saved' in such conditions is a fallacy. And drip irrigation is the red herring giving substance to this claim and distracting us from the simple (but merciless) arithmetic of a zero-sum game.

That nobody knows what the savings could be is probably well illustrated by the target of the PNEEI (850 Mm3, sometimes rounded up to 1 Bm3, or 1.4 Bm3[58]), later inflated to 2.5 Bm3 in the National Water strategy (Monitor Group 2008), with 1.6-1.7 Bm3 of predicted savings by 2030 for the sole conversion of 900,000 ha to drip. FAO's (2015) mention of the 2009 Water Strategy puts the potential for water savings in irrigation at 2 Bm3 for the conversion to drip and 0.4 Bm3 for the improvement of distribution networks. In 2014, the CESE (2014) indicated that the PNEEI would achieve 80% of a potential of water saving of 2 Bm3 by 2020. Recently the Ministry of agriculture in a meeting in Rabat announced that the conversion to drip of 550,000 ha would realize 4 Bm3 of water savings by the end of the year (2017)… (L'Economiste, 2017). Numbers produced without logic and supporting scientific evidence are probably the outcome of a cross-multiplication whereby target numbers become real by mere declaration. Unsurprisingly, in 2016 the government was unable to respond to the World Bank's inquiry about how much water had been saved by its programs.

Through good relationships with donors and development banks, and self-congratulatory statements, Morocco often appears as the 'good student in the classroom' (Akesbi, 2014). The World Bank (2016) recently praised "Morocco's approach [that] aims to reap the triple win of adapting to climate change while lessening its impact and creating new opportunities", and affirmed that "Morocco is making an effort to conserve its underground aquifers, a natural source of fresh water that, if left clean and undisturbed, replenishes itself. It's a win for the environment and for current and future generations of Moroccans". Such unqualified statements combined with complacent media reporting are unhelpful and contribute to obfuscation and a perpetuation of the grim reality.

1.10 Unclear political will

The situation described above clearly points to a contradiction between sectoral policies, with agricultural interests and the clout of the Ministry of agriculture evidently outplaying those of the administrations in charge of water and the environment. As mentioned earlier, this translates into contradictory statements in official documents and discourses.

The lack of political will to solve this contradiction can be illustrated in several ways. First it is striking that the dispositive planned by the 1995 law to declare overexploited aquifers as 'safeguard' or 'prohibition zones' has yet to be implemented, despite the dramatic situation of most major aquifers in the country (and the support or request of the proper ABHs). In view of the critical status of the Haouz aquifer, the director of the ABH for the Tensift issued an administrative circular in 2008 suspending the granting of new drilling licenses. But such measures can be overridden by higher authorities and it is hard to escape the conclusion that there is limited political resolve to tackle overdraft for fear of curtailing the source of important social and political gains.

A second indication of this state of affairs, mentioned earlier, are the loopholes created by the Ministry of agriculture that allow farmers to bypass the groundwater-use authorization process of the ABHs. Farmers can apply for reconversion subsidies by signing a letter certifying that they

[58] See FAO, 2014.

were using the well prior to 2005 (Saïss) or by presenting a document demonstrating that they have made an official request to legalize an allegedly old well (Haouz).

Several factors give the distinct impression of a lack of political will when it comes to the enforcement of difficult regulatory measures. These include the ineffectiveness of the water police, the failure by the ABHs to take action against people openly violating the law (for example irrigating crops with a well authorized only for domestic use or cattle), the fact that authorized wells must be equipped with meters (at the user's expense) which are nowhere to be seen on the ground, the fact that water fees (also made compulsory by the 1995 law) are maintained at an extremely low level, and that the 'aquifer contract' signed in the Souss basin in 2009 has so far largely remained a dead letter (BRLi and Agroconcept, 2013).

Further questions are raised by the delay in divulgating the National Water Masterplan, finalized in 2014 (TelQuel, 2014), the putting aside (after only one year) of the Inter-ministerial Committee on Water established in 2001 "to ensure close coordination of all the ministries regarding water issues" (CIE, 2014), and the failure by the *Conseil Supérieur de l'Eau et du Climat* to hold a meeting since 2001.

By stressing that the governance of groundwater resources is "a major challenge that many regions should improve given their responsibilities towards food security and poverty reduction" (Masolia News, 2014), the minister of agriculture is implying that there is something called 'good governance', which regions should adhere to and which would provide a kind of institutional fix to the issue of water scarcity so that objectives of food security and poverty reduction can be met. Yet by suggesting that there exists some technological or institutional fix he is ignoring – or fails to understand – hydrologic realities in favor of political objectives or ambitions. This is a well-identified feature of the basin-closure process (Molle, 2008).

It is apparent that such technicalities are swept under the rug as they run contrary to the objectives and political messages in the PMV. In his speech at the seminar on aquifer contracts in 2014 the minister of agriculture was careful to remind his audience that the PMV had been launched directly by the king[59], thereby strengthening its legitimacy and staving off any criticism.

Finally, it can be hypothesized that the current lack of will to face the country's hydrological reality and contemplate the contradictions of drip irrigation development is partly linked to a technological fascination that fosters 'a positive interpretation' of the technology (Venot, 2016), as well as to private and bureaucratic interests. Drip expansion has generated "an active inter-related socio-technical network involved in the sale, manufacturing, fitting and use of drip-irrigation systems" (Benouniche et al., 2014c) that arose in response to the billion euros of public money spent on irrigation modernization. Likewise, bureaucratic circles commonly thrive on special projects and aid money that have enhanced department budgets, bureaucratic power and personal fringe benefits (Lazarev, 2012).

1.11 Monitoring and assessment capacity

In a situation of extreme commitment of water resources, an elaborate water accounting capacity is in order. When basins close, bi-directional fluxes between surface and groundwater, return flows, changes in stock, or water quantity/quality relationships need to be captured with more accuracy. The reason being that while in open basins the large availability of blue water 'dilutes' these interactions and their associated impacts, in closed basins there is no 'slack' in a

[59] "So the Green Morocco Plan launched by his Majesty in 2008 fits perfectly in this high guidance Royal control and the economy of water at the heart of this strategy to ensure sustainable agricultural development and food security" (Akhannouch, 2014).

system that quickly evolves to a zero-sum game. PDAIREs, and their articulation within a National Water Masterplan, are a good response to planning needs but planning is always contingent upon the quality of information available and the hypotheses made. The new Water Law (36-15) has rightly put emphasis on the strengthening of a national water information system. It is beyond the scope of this report to analyze the planning process but a few observations about some worrying elements are mentioned briefly here.

Incomplete data. Behind the numbers provided by technical studies, it is recognized that monitoring "does not allow the production of reliable information on water withdrawals", to quote the Minister of Water (L'Economiste, 2014b). Although water data collection is quite advanced in Morocco compared to many other countries, it is increasingly inadequate in a situation of basin closure. This is particularly true for groundwater. A 'potential' is given for each aquifer but there is no open discussion about how these numbers have been estimated, or about the concept of 'safe yield' for the country in general.

A very detailed account of the Haouz aquifer (Tanouti et al., 2016) considers all the terms of the water balance through the ranges of the values appearing in the literature. It shows that in an average year the aquifer’s deficit varies between 100 and 300 Mm3, depending on the assumptions made. All variables in the balance contain significant degrees of uncertainty and there is therefore no accuracy on the final deficit.

Extent of groundwater-based private irrigation. There is insufficient monitoring of groundwater-based irrigation (admittedly a difficult task). The figure of 441,430 ha which is invariably given was originally reported in 2004 (cited in Oubalkace, 2007) and is still in use today (see CESE, 2014). This suggests that the continued expansion of private irrigation is not well accounted for and grossly underestimated. It is striking that the chart showing the magnitude of overexploitation in main aquifers given by the Monitor Group (2008) includes the category 'overexploitation not estimated'. This accounts for the high number of unknown illegal wells (see above) and the uncertainty on actual abstraction.

Double counting. The surface and groundwater currently available are presented as two separate sources of water (typically two stocks of 18 and 4 Bm3 respectively, which can be 'mobilized' for human use)[60] without acknowledging that (a diminishing) proportion of surface water comes from groundwater itself.[61] Abstracting more groundwater has therefore resulted in a reduction, in, or even stoppage of, return flow to springs, khettaras and riverbeds. This means that instead of permitting agricultural expansion groundwater has largely been reallocated from the former appropriators of these return flows to tubewell owners[62]. There are only passing references to this phenomenon in Morocco, including Doukkali (2005), who reports that "it is estimated that the expansion of private and groundwater-based irrigation has reduced [countrywide] the irrigated area in the small- and medium-scale irrigation perimeters to the tune of 150,000–200,000 hectares".

This general situation can be illustrated by the case of the Saïss Plain. In the 1970s farmers were irrigating 37,000 ha from around 100 springs (with a total discharge of 6 m^3/s) and small wadis. There are now at least 10,000 tubewells in the plain; many springs have seen their discharge

[60] Likewise the conception that "nowadays agriculture consumes around 10 Bm3 per year but *allows flow to nature* of 6 Bm^3, that is 60% on average" (El Alaoui ,2006; emphasis added) is misleading. It includes a typical confusion between diversions and consumption/depletion, and suggests that the return flows go 'to nature', while in reality the largest part of the 6 Bm^3 is reused and consumed.

[61] By way of example, it is estimated that as much as half the flow of the Colorado River comes from the discharge of aquifers back to the river system (baseflow).

[62] If the sum of all newly irrigated areas has increased this has been allowed by the depletion of the aquifer.

dramatically reduced; and wadi Fès has effectively dried up. A total area of nearly 50,000 ha is irrigated but at the cost of a depletion of the aquifer by around 100 Mm3/year (Bouignane and Serrhini, 2015). In addition the recharge area in the Middle Atlas is also being developed, which is causing a reduction in recharge (ibid.).

Dam capacities do not add up. Successive dams may only marginally increase the storage capacity. The basin of the Oum Rbia provides a good illustration, since the commissioning of the dam Al Hansali in 2002 with a significant capacity in the order of 700 Mm3, had no significant impact in terms of the mobilization of water resources for the Tadla and Doukkala schemes (Belghiti, 2009).

Available water resources are declining. Available resources have declined by 33% between the 1945-1970 and 1970-2000 periods (Belghiti, 2008). Studies carried out in the late 2000s to update river basin masterplans found a decrease of "regularized volumes" by around 30%, compared with earlier masterplans [carried out around 30 years earlier]. The difference is even sharper at the level of river basins such as Bouregreg, Oum Er Rbiâ and Sebou (46%, 45% and 38% respectively) (El Gueddari and Arrifi, 2009).

Climate change predictions point to a continued trend in the occurrence of extreme events and in rainfall reduction, and "the country's water resources, both superficial and groundwater, are expected to slump by around a further 15% to 20% by 2030" (HCP, 2007)[63]. Yet, rather incredibly, PDAIREs do not acknowledge these predicted reductions and plan water resources on the basis of current water availability, with no mention of climate change. Supplementary studies have been conducted since the publication of the PDAIREs on the impact of climate change in some basins, such as the Oum Er Rbia where the supply-demand deficit estimated by the PDAIRE at around 560 Mm3 for 2030 was in fact found to be around 1500 Mm3, with the observed climate trends and forecasts available to date (Hydraumet, 2013).[64]

Dams are losing storage capacity. The 128 large dams in the country have lost 10% of their capacity, but this rate is much higher in some basins, such as in the Moulouya, where they have lost 39% of their capacity, while 75 Mm³ continue to be lost each year (FAO, 2014; Lemaizi, 2015). The Nakhla dam in Tetouan is now totally sedimented. On the Moulouya River the Mohammed V dam is sedimented at 55% (Monitor Group, 2008). Fortunately this phenomenon is more acute in Mediterranean basins where water resources are more abundant.

Overbuilding of river basins. As mentioned above, 140,000 ha of additional land to be irrigated are planned under existing dams (Belghiti, 2010). Although the Wahda dam is storing unused water and has the potential to irrigate more land, more attention should be given to keeping some slack to provide additional flexibility in management. Whereas in fact all new dams also come with new irrigated areas, as is the case with the Mdez dam (to compensate upstream people whose land is going to be flooded, as well as in the Saïss Plain[65]). The recent dam on wadi

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[63] Aoubouazza et al. (2013) forecast a drop in water availability between 14% and 23% by 2050, while downscaling of IPCC models on a catchment of the Tensift River basin pointed to an increase in temperature of about 2-3 °C and a reduction in precipitation of 40-60% by 2100 (Rochdane et al., 2012). Morocco is considered to be a country with very high water stress by the World Resource Institute (Luo et al., 2015) – a situation that will worsen by 2040.

[64] "The water supply and demand balance for 2030 (the current PDAIRE) is optimistic and does not sufficiently integrate climate risk and its possible effect on the potential water of the area to this date: the supply-demand deficit estimated around 560 Mm3 for 2030 should actually be around 1500 Mm3, with the climate hydro trend and forecasts available today" (Hydraumet, 2013).

[65] Under present conditions, more water brought to the Saïss (125 Mm3 from the Mdez dam, which is under construction) will beget more expansion of irrigated agriculture in the Fez-Meknes Plain (Saïss), the area of which is 160,000 ha, enough to absorb 1 Bm3 (Bouignane and Serrhini, 2015).

Asif el Mal, south of Marrakesh, and the future dam on wadi Chichaoua, for example, are also to be associated with expanded irrigation systems.

In summary, despite a hydrological monitoring network that is fairly extensive compared with other countries in the MENA region, the estimations of future supply and demand are somewhat crude in the absence of clear consideration of the growing complexity of hydrological processes, the uncertainties linked to climate change, and diffuse groundwater use.

6. Conclusions: a poisoned chalice

The subsidized shift to drip irrigation brings substantial economic benefits, ranging from higher yields and incomes and reduced percolation of agrochemicals to the aquifer to lower labor requirements and energy bills (when the pumping of deep groundwater is reduced), while facilitating a shift to cash crops and higher water productivity. However, the benefits, touted with slogans such as "irrigation must improve its performance with less water and in a more sustainable manner" (MAPM, 2007b) and achieving "three times the production with half the water" (L'Economiste, 2016) run counter to hydrologic realities.

The actual implication of the introduction of micro-irrigation in terms of the circulation of water through plots, systems and basins, and more generally the question of the scale-sensitivity of the concept of efficiency in water use, has been the subject of considerable literature and debate. Although the technical details may at times become complex, some of the well-accepted conclusions, though relatively straightforward, have often failed to make their way to decision-makers.

Even by conservative hypotheses it is very unlikely that drip irrigation will reduce plot-level water consumption (ET), that is, will achieve 'real' water savings, since the type of cropping patterns adopted and the intensification observed in Morocco clearly point to the opposite: *increased depletion*. This is consistent with the literature but, beyond this debate, the incentives provided for the *expansion* of irrigated agriculture (most particularly in the deficit basins of the Bouregreg, Oum Er Rbia, Tensift, Souss-Massa-Draâ, Tafilalet or in the Saïss Plain) are even more problematic: expansion occurs at the farm level (for those farmers shifting to drip irrigation and with available adjacent land), and at basin level, with state investments in new public irrigation schemes, as well as groundwater licenses given to investors.

Morocco must wake up to the reality that the intensification and expansion of agriculture associated with drip irrigation, as fostered by the Plan Maroc Vert, cause increased resource depletion by evapotranspiration, and this is only made possible by a) increasingly drawing from northern 'surplus' basins (Sebou, and more marginally Loukkos), which will eventually close, b) worsening the deficit of major aquifers, and c) over-developing the potential demand and thereby creating heightened vulnerabilities in the face of climate variability. Most worryingly, PDAIRE scenarios for 2030 disregard climate change and the warnings that the 30% reduction in water resources observed over the past 30 years might just be replicated in the future.

The technical (drip irrigation), economic (water pricing) and institutional (aquifer contracts) *fixes* of the water demand management toolbox put forward by the government are *red herrings* that distract from the evidence that the country is squeezing itself dry by increasing water resources development and depletion. The solutions put forward have counterintuitive, negative consequences on water consumption (drip, in most settings), limited potential (pricing), and/or are extremely difficult to operate (pricing and metering, aquifer contracts). International experience certainly does not support the hypothesis that these measures can jointly 'do the trick' and stem overexploitation; even more so because the government's current policies are achieving just the opposite, by subsidizing intensification and expansion rather than controlling and limiting them to places where they are still compatible with the resource available.

Pressing political realities are understandable and may well encourage investments that are seen to provide employment and create wealth in rural areas. But these short-term political or private gains are a Faustian bargain. As Bouignane and Serrhini (2015) put it: "we have sounded the alarm. We know it's a very complex problem, latent and invisible. We are procrastinating because we're not ready to sacrifice what we are gaining at present, and because there are conflicting interests. […] the current trend follows the worst-case scenario." This is a wake-up call that political incantations mask the grim reality that in a closed basin you cannot 'create' new water by any technical fix or otherwise.[66]

According to the minister of agriculture, the implementation of the PMV testifies to the "relevance of technical control and rationalization of water as an essential lever to improve productivity and adaptation to climate change" (L'Economiste, 2016). Alleged water conservation is now branded as a response to climate change, but the growth subsidized by the PMV is in fact absorbing the remaining 'slack' in the system, as the overall depletion of the resource is increased in line with the augmentation of production. Vulnerabilities increase rather than decrease. The growth in tree plantations[67] implies that water demand is becoming rigid and structural, hard to adjust in times of water shortage. While dams have been praised for sheltering irrigated agriculture from disaster, such as in 2015-16 when rain-fed agriculture was severely impacted, the opposite is true for a three-year drought such as that experienced in the early 1980s. The carry-over stocks are too limited, and an overdeveloped demand would not be met, with dramatic consequences.

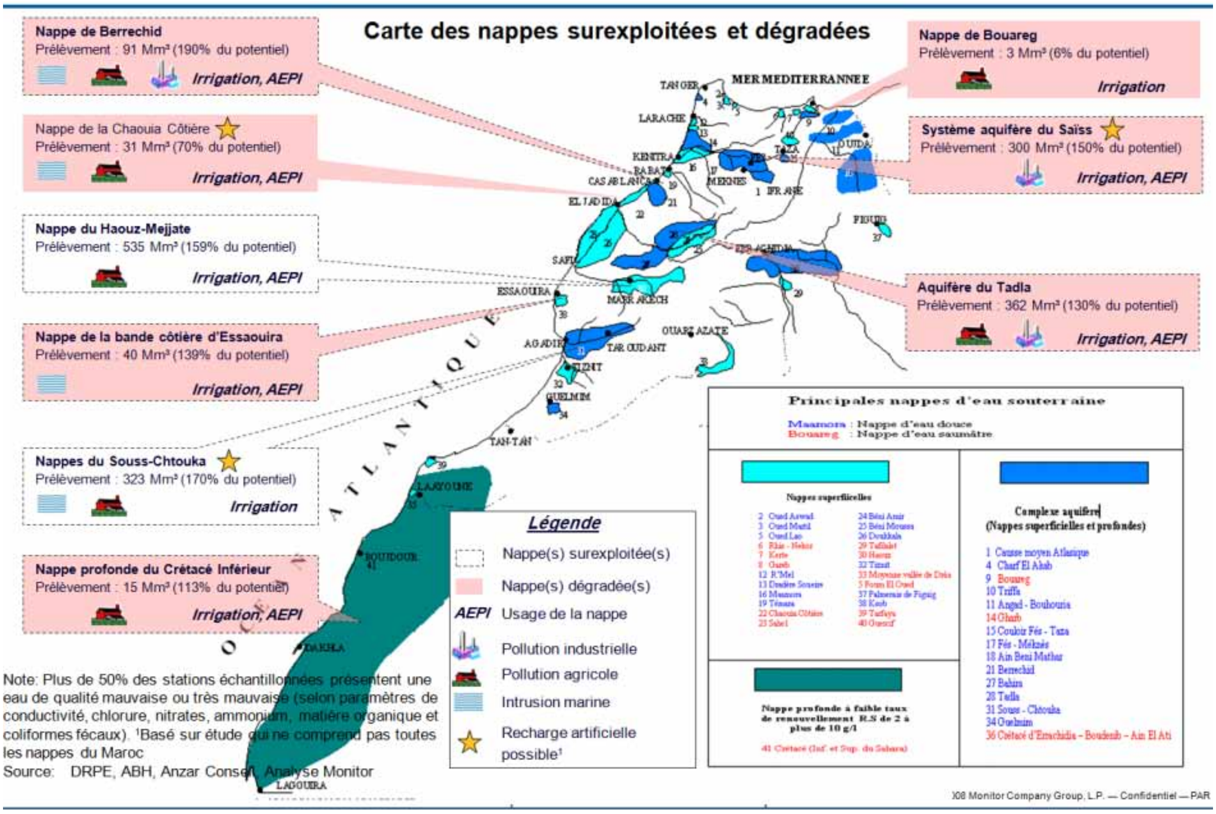
A fully fledged analysis of what could be done to get out of the current gridlock is beyond the scope of this report. However, some key points must be emphasized: firstly, before thinking of reducing the abstraction by existing users the most urgent measure is to quell the expansion of groundwater-based agriculture on overexploited aquifers: the provisions for establishing prohibition zones already exist in the 1995 law but this of course requires political will that has so far been lacking. Subsidies to agricultural well drilling, through the PMV or otherwise, should be limited to carefully delineated areas, and the authority of the ABHs should prevail. Secondly, the conversion to drip irrigation has to be seen through its real and effective vantage points (in raising land and water productivity) but not branded as a means of saving water. The benefits of shifting to drip irrigation are substantial and may be worth a moderate increase in water consumption at the plot level, but this should be done according to zoning that takes into consideration the status of the resource. Thirdly, more detailed water accounting must be carried out for each river basin, aquifer and irrigation scheme. At present the available surface and groundwater are presented as separate sources of water, without sufficiently recognizing their interactions or the hydrologic complexity of closed basins. Short-term political and financial interests should not be allowed to dominate or guide policymaking. Neither should they be able to delay an acknowledgement of the fact that the predicted reduction in water availability should prompt Morocco to adopt a much more cautious approach to the management of its water resources.

[66] Unless you desalinate or import water from another basin.

[67] For example the area planted with citrus has grown from 74,000 ha in 2000 to 119,000 ha in 2014 (see www.agriculture.gov.ma/sites/default/files/131126-note_veille_strategique_agrumes-sl.pdf);

7. Appendices

1.12 Main aquifers in Morocco (Monitor Group, 2008)



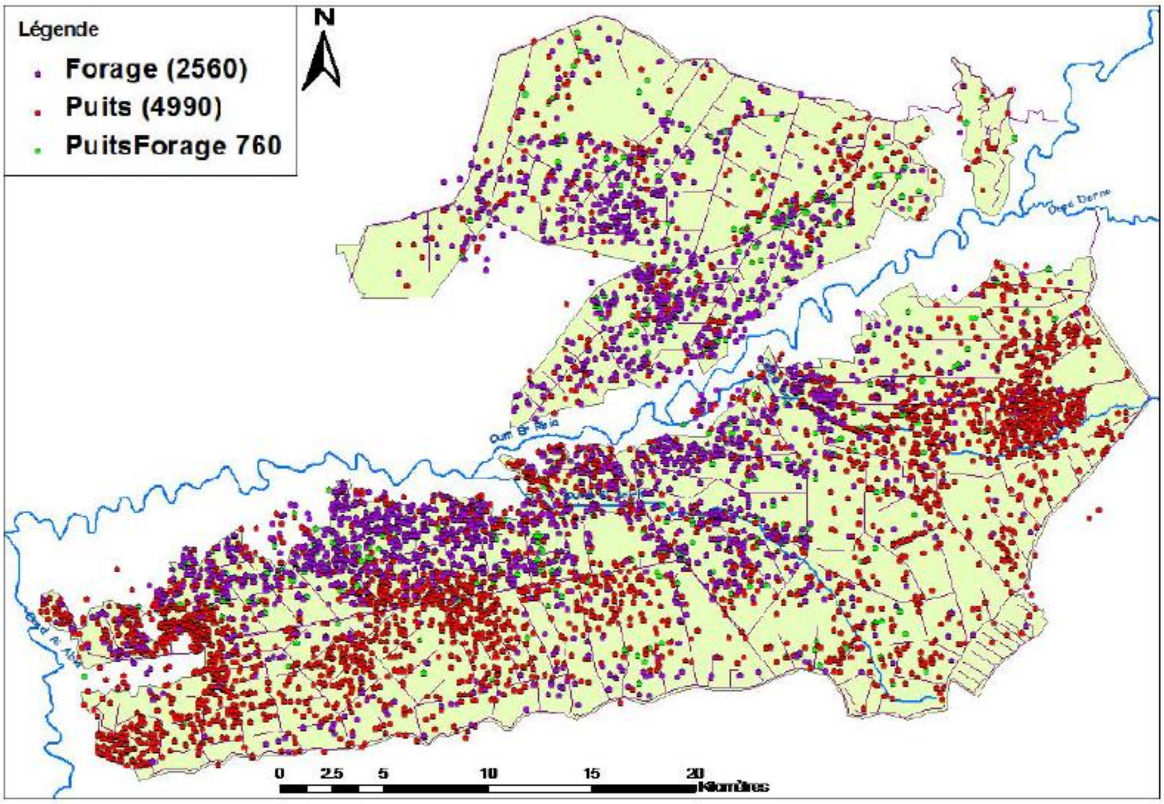
1.13 Reduction in estimated available resources (Belghiti, 2010)

Volumes régularisables par les barrages à l'horizon 2020 selon les études récentes montrent une diminution de **32%** par rapport à ceux prévus par les anciens plans directeurs

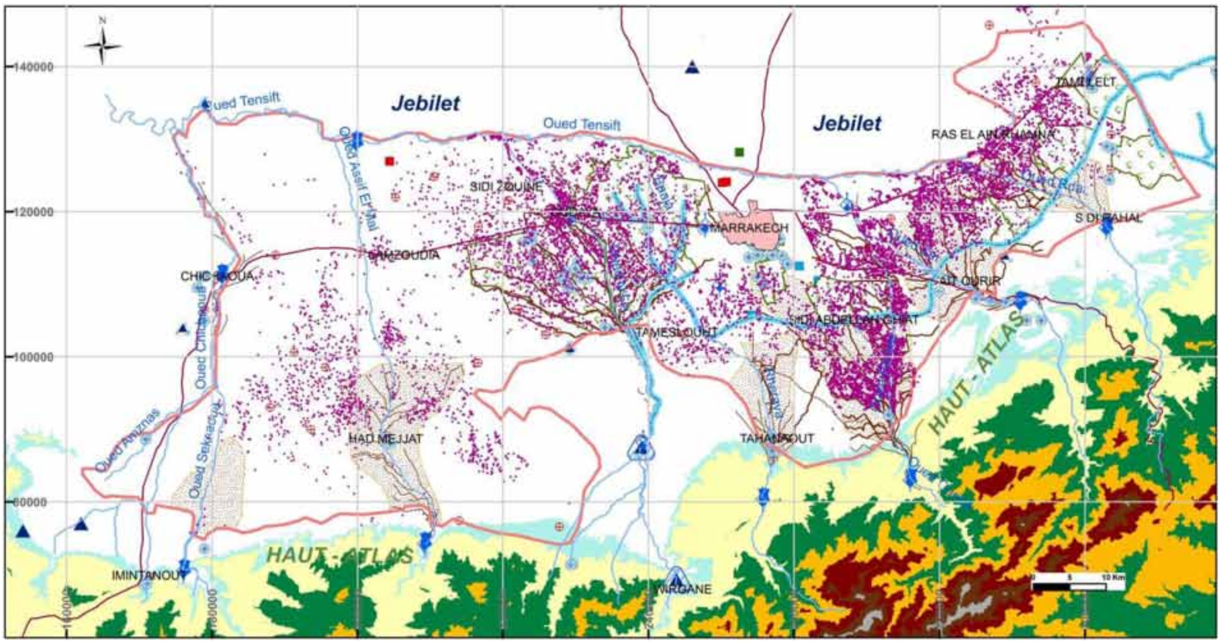
Bassins	Plans Directeurs	Etudes récentes	Ecart
Oum Er-Rbiâ	3.950	2.190	45%
Sebou	4.467	2.748	38%
Loukkos, Tangérois et Côt. Médit.	1.077	867	19%
Moulouya	1.42	884	15%
Bouregreg	662	358	46%
Tensift	725	615	15%
Souss-Massa	615	576	6%
Sud Atlasique	974	974	-
TOTAL	**13.512**	**9.212**	**32%**

1.14 Examples of well density in large-scale public schemes

Wells in the Tadla scheme (2006) (Hammani and Kuper, 2008)



Haouz of Marrakech (ABHT, 2014)



1.15 Expansion of villas and associated water requirements in the Haouz

1.16 Satellite images showing expansion of agriculture in formerly rain fed or fallow land

Examples of intensive tree farming recently set up (2009 – 2016) (zone H2)

Recent expansion of agriculture (Chichaoua road)

1.17 Estimated water balance of main aquifers

FAO 2008

	Ressources renouvelables naturelles (Mm3/an)	Ressources exploitées (Mm3/an)	Ressources exploitables (Mm3/an)	Volumes surexploités (Mm3/an)
Loukkos	406,3	63,6	58,6	5,0
Moulouya	267,5	255,3	200,3	55,1
Sebou	1 561,8	769,4	678,4	91,0
BR Chawia	97,0	144,6	71,4	73,2
OER	619,3	582,8	467,8	115,1
Tensift	167,5	552,6	340,5	212,1
Souss	336,8	641,4	345,0	296,4
Draa	283,2	258,8	236,5	22,3
Ziz(*)	312,6	220,0	174,3	45,7
Saquiat El Hamra	2,5	18,9	2,5	16,4
Total	4 054,5	3 507,4	2 575,1	932,3

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