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MCA4climate: A practical framework for planning pro-development climate policies

Case Study:

Water Resources Management and Climate Change Adaptation in the Sana'a Basin, Yemen

Contribution to the MCA4climate initiative

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Practical Note

This case study represents an illustration of how the MCA4climate initiative may be applied under more realistic settings. Though it draws on real data, it does not represent a proper pilot application of the MCA4climate approach, but only a snapshot of how this may be applied in practice (the case-study was mostly centred around a two-day workshop at UNEP offices in Paris). For an overview of the general MCA4climate initiative please see the main MCA4climate report and other associated documents available on www.mca4climate.info. For further information, please contact the UNEP team, Serban Scrieciu, Sophy Bristow, Daniel Puig or Mark Radka at unep.tie@unep.org.

Introduction

The main aim of this case study was to test the MCA4climate policy-evaluation framework in a situation where policy options were interdependent. A secondary aim was to apply the framework under different climate scenarios and account for climate uncertainty. Yemen was chosen because it has pressing near-term problems with water management that would need to be addressed in conjunction with any planning for adaptation to the effects of climate change.(1)

Given Yemen's heterogeneity, we decided to focus on the impacts and performance of policy options in a single hydrologic basin. In other words, policies might be implemented at a national level, but we would evaluate their likely performance locally. The Sana'a basin was selected as the target basin because it contains both extensive irrigated agriculture and the rapidly-growing capital city, for which water and sanitation services are woefully inadequate. In addition, the basin is facing rapid depletion of its limited groundwater resources as a result of the explosive growth of groundwater pumping for irrigated agriculture that followed the introduction of diesel pumps in the 1970s and heavily subsidized diesel prices. This has resulted in a short-term agricultural boom period, but alarming drops in aquifer levels and loss of springs that formerly provided critical community water supplies. Only in recent years has the central government reduced fuel subsidies and launched a programme of legal reform intended to constrain further expansion of groundwater use.

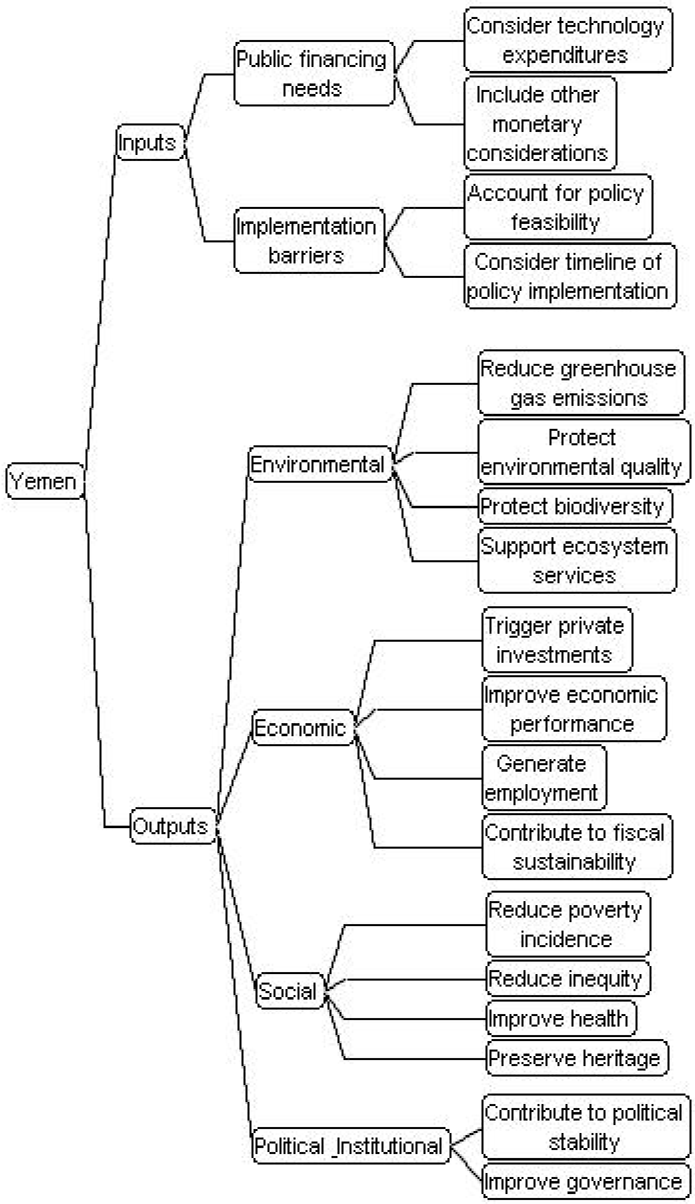
Climate change could exacerbate an already worsening water crisis in the Sana'a basin. Any climate adaptation options would, therefore, need to reinforce efforts to address the current crisis. Thus, the set of adaptation options selected for analysis reflects the types of policies that are being implemented, or have been suggested, to deal with the on-going over-exploitation of groundwater resources. The major difference is that we would propose a more rapid and larger effort for each option than is currently planned.

Criteria and policy options

The first step was to adapt the generic criteria tree to evaluate the relative merits of alternative water-sector adaptation options. The tree was extended to include more detailed water theme-specific criteria. However, based on what was learned in the first case study and to facilitate the exercise of evaluating the policies, we decided to concentrate on scoring options at the higher up 3rd-level criteria (see Figure 1), using the water theme-specific criteria only to inform our thinking about how we would do this.

1 The case-study had as a starting a report by the World Bank on climate change impacts on the water and agriculture sectors in Yemen (World Bank, 2010).

Figure 1: Criteria tree for evaluating polices to improve water management in Yemen (case study)



We selected a set of eight options for analysis, including three basin-wide options (labelled BW1, BW2 and BW3); three focused on the urban water sector (U1, U2 and U3) and two focused on rural agricultural water use (R1 and R2). Some of these are themselves actually packages of measures that would be implemented together. The adaptation options are described in Table 1:

Table 1: *Policy options to improve water management in Yemen*

Policy	Description
Basin-wide	
B1: Strengthen basin-wide water planning and governance	The most complex and comprehensive of the options considered. Accelerated implementation of the following reforms, which are already underway, was assumed: Establishment of a process for basin-wide determination of limits on total water use by area and type Requirement for full coverage of irrigated land within water user associations (WUAs) Enhanced powers and responsibilities of WUAs to implement and enforce limits on well-drilling and water extraction Legal mechanisms for transfers of water extraction rights and land easements
B2: Retire lands from agricultural use	Creation of a public programme to purchase land currently used for irrigated agriculture and to return it to a natural state. A target of 25 % reduction (c.6 000 ha) in irrigated hectares was assumed. The effectiveness of this option would depend heavily on implementation of other governance measures, because without those reforms, there would be nothing to keep other land-owners from expanding irrigation operations on other lands.
B3: Integrate land and water management	A set of projects to augment groundwater recharge and limit drawdown by instituting a low-cost loan or matching grant programme to maintain and restore terraces for soil and water conservation, and build spate check dams and recharge basins.

Urban	
U1: Protect the quality and usability of existing water resources	Reverse the present trend of urban-source pollution of shallow groundwater resources, primarily from untreated sewerage, by improving sewerage and waste-water treatment systems and by providing other waste management services.
U2: Provide Desalinized sea-water to Sana'a	Install solar-powered desalination plants on the coast and use solar power to pump the water uphill to the Sana'a Basin. Assumes a 1 billion cubic metre/year plant and pipeline at a capital cost of USD $6 billion with an cost of delivered water of USD 1 per cubic metre.
U3: Implement urban water demand management	Reform public water tariffs for the purpose of collecting sufficient funding for system improvements, including developing a system for metering, billing and revenue collection that would use increasing block rate pricing to keep lifeline water rates low while charging higher rates to households that use large amounts of water. It was assumed that this policy would provide enough revenue to pay for major system improvements that would allow all urban households to have access to safe, reliable public water supplies, although not necessarily in-home taps.
Rural	
R1 Create incentives to promote efficient use of agricultural water.	Eliminate remaining subsidies on diesel, as well as the agricultural import restrictions that had helped to spur the race to exploit groundwater reserves for irrigated agriculture. It was assumed that the government would continue raising diesel prices to world-market levels, and would eliminate import restrictions/tariffs on fruits, vegetables and qat.
R2: Create incentives to promote demand-side technology uptake.	Extend current programmes aimed at increasing crop output and income per unit of irrigation water consumed (e.g. provide low-cost loans to install piped irrigation systems, mulching and similar investments to conserve water). It was assumed that the government would make these programmes available to any willing farmer in the Sana'a Basin. It was also assumed that the policy would be implemented without any restrictions on eligibility or on the total extent of irrigated land in the basin.

It was known at the start of the work on this case study that the adaptation options are not independent of one another. This became clearer as the work progressed. In particular, the presence or absence of governance reforms would have significant impacts on behavioural responses to other policy options, and therefore on their effectiveness. Such governance reforms would first clarify who has the right to use water, the quantitative limits on the use rights, and the locus of decision-making authority to modify use rights. The reforms also would create enforcement mechanisms to ensure compliance with legally-defined rights and obligations. Similarly, monitoring systems are a necessary component of any water management programme. As a result, we assumed that basic physical monitoring systems would be in place (even where they are currently inadequate) and that monitoring of water use, and of activities that could jeopardize water quality would occur as part of a package of governance reforms.

Scoring the options

Before the options were scored, it was necessary to decide how to take into account the uncertainty surrounding the impact of climate change on Yemen. Two climate-change scenarios prepared by the World Bank (2010) were selected: a mid-range scenario with moderate warming (an increase of 3.1^0 Celsius over 1990 levels by the 2080s) and small precipitation changes (3% fall), and a hot-dry scenario with amplified warming (+4.5^0 C) and significant declines in precipitation (-24%) resulting in major reductions in runoff and recharge. These differences would have large impacts on water availability and on policy effectiveness over the long term.

The initial set of scorings rated the options individually and did not assume that the governance reforms (which make up option BW1) were in place when other options were scored. Because many of the other options would perform poorly in the absence of governance reforms, and because there are likely to be other interactions among the options, climate adaptation policymakers would, in reality, need to compare portfolios of options. Another issue that policymakers would need to consider is the sequencing of policies. Clearly, low hanging fruit – actions that cost little, but promise significant improvements – should be pursued first. In practice, the issue of interdependence among options affects the appropriate sequencing and packaging of options into portfolios of activities that need to be pursued in tandem in order to be most effective.

In the case study, the individual options were initially scored for each scenario according to how well they would serve each criterion when viewed from the perspective of the end of the period of analysis – the decade of the 2080s. A score of 100 was given to the policy that seemed to best serve the criterion and a zero to the one that would be least effective (or even damaging). There are some striking differences in the scorings between the two scenarios, for example:

- BW2 and R2 perform better in the mid-range scenario. In the case of BW2 (retiring agricultural lands) there is a dramatic reduction in the expected environmental benefits in the hot-dry scenario compared to the mid-range scenario, as seen in Figure 2. This reflects the assessment that if the governance reforms are not strengthened significantly beyond those already underway, there will be very little water available by the 2080s and little groundwater-based irrigation left to manage in the hot-dry scenario. In the mid-range scenario, it was assumed that the reforms currently underway would be successful in extending the life of the aquifer and that steady-state groundwater abstractions could be maintained at a rate equivalent to average annual recharge.

- U2 (desalinized water for Sana'a), BW1 (strengthen basin-wide planning and governance) and R1 (promote efficient use of agricultural water) all perform better in the hot-dry scenario relative to mid-range scenarios, as seen in Figures 3, 4 and 5.

Figure 2: Scoring of policy options to improve water management in Yemen: BW2 (retiring land from agricultural use) in the mid-range and hot-dry scenarios

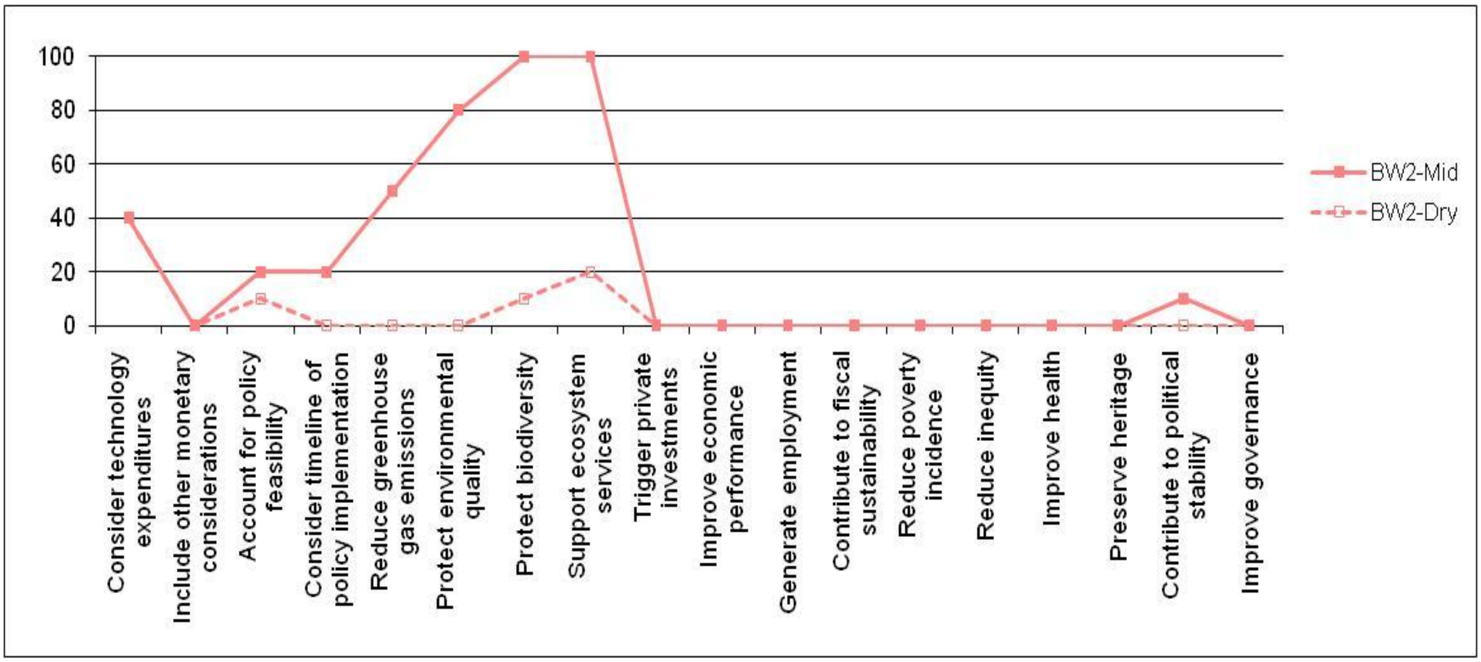


Figure 3: Scoring of policy options to improve water management in Yemen: U2 (provide desalinized sea-water to Sana'a) in the mid-range and hot-dry scenarios

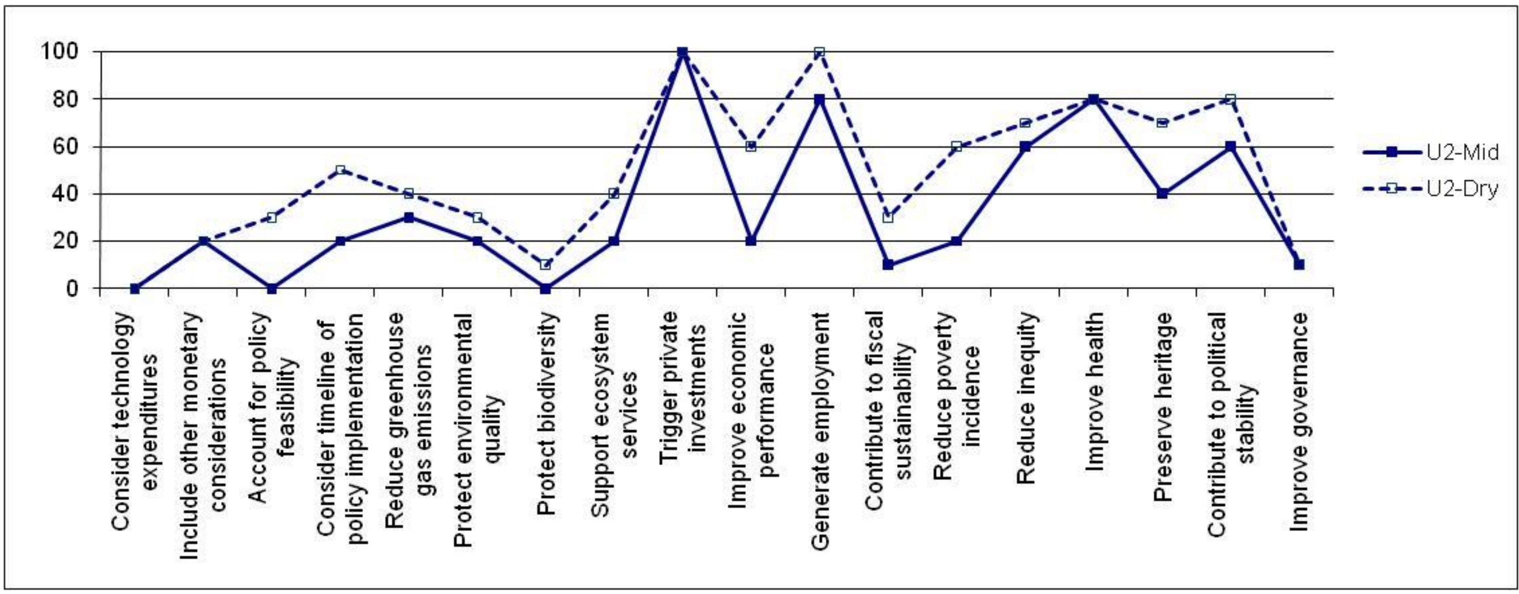


Figure 4: Scoring of policy options to improve water management in Yemen: BW1 (strengthen basin-wide water planning and governance) in the mid-range and hot-dry scenarios

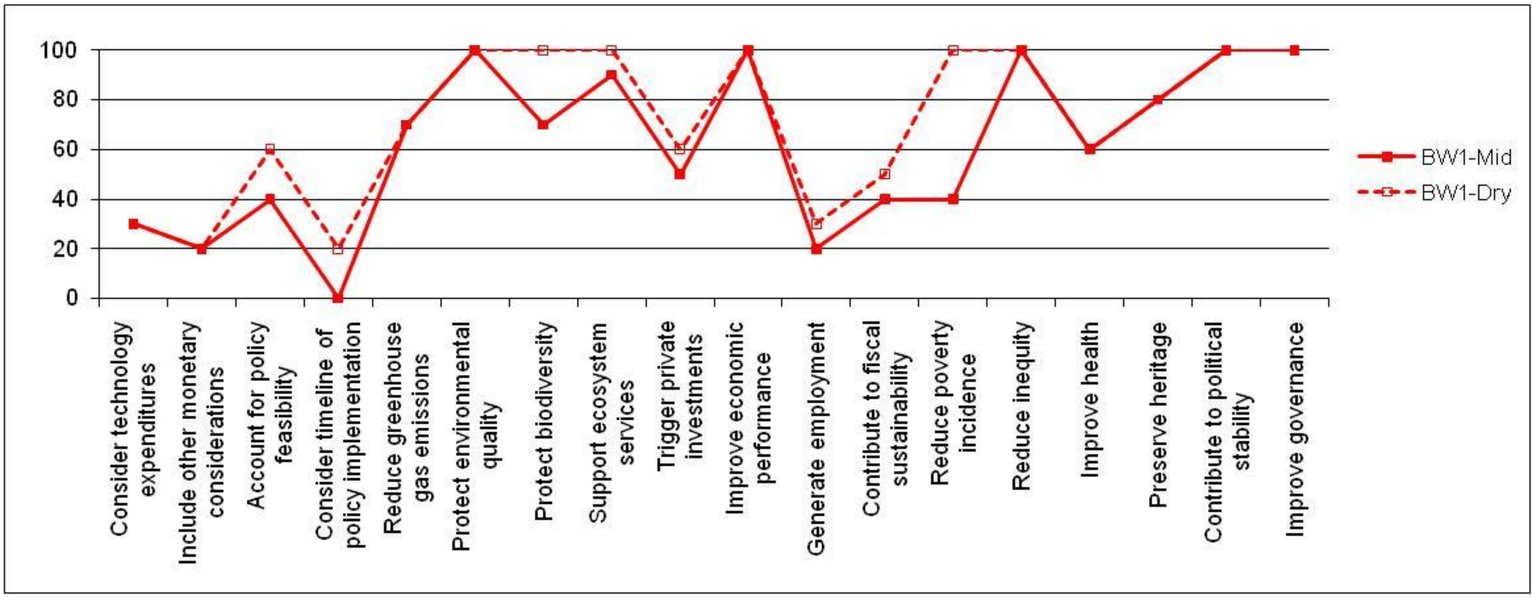
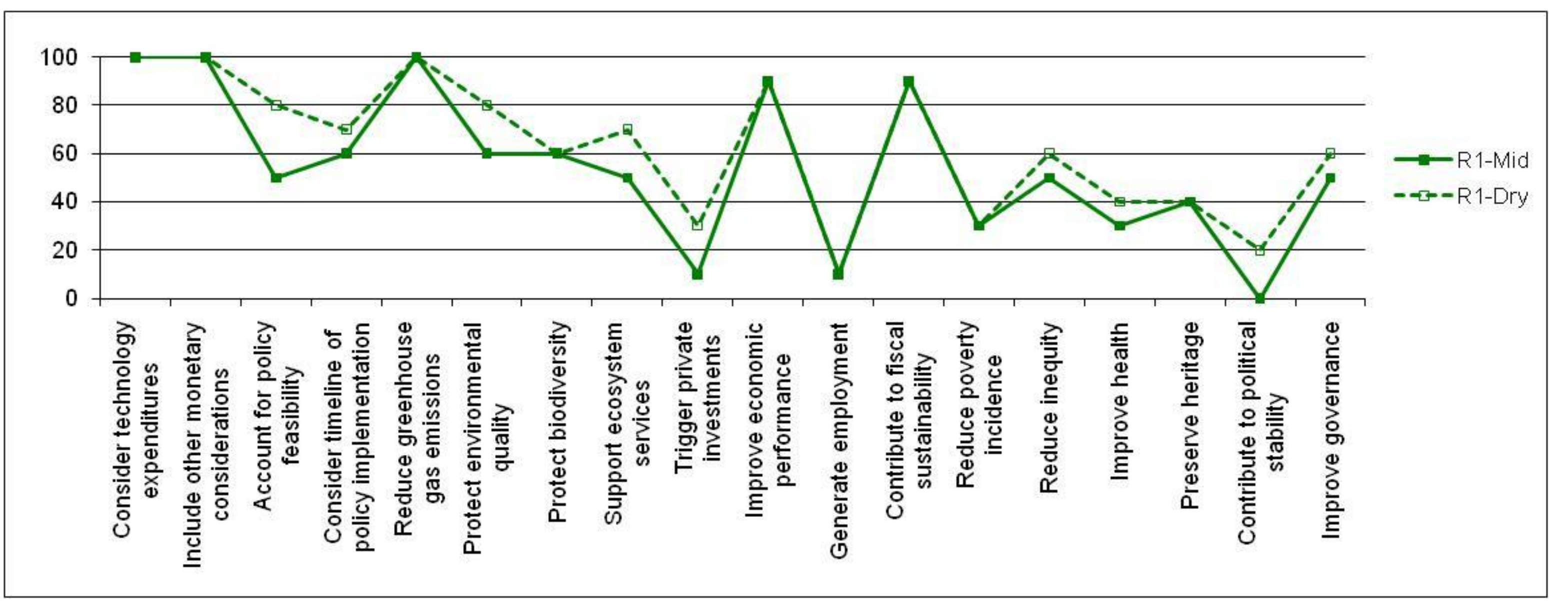


Figure 5: Scoring of policy options to improve water management in Yemen: R1 (create incentives to promote efficient use of agricultural water) in the mid-range and hot-dry scenarios



Results and sensitivity analysis

The weighting of criteria at the 3rd level of the tree used the swing-weighting process. As the analysis is illustrative and the group did not know what the priorities of real decision-makers would be, a rough five-point scale was used to capture these initial judgements.

As a starting point the, weighting of criteria at the 2nd level of the criteria tree put greater emphasis on implementation barriers within inputs and weighted the four output families proportionally to the number of 3rd-level criteria (so the political-institutional family weight is half that of each of the economic, environmental and social families).(2) The weights were combined with the scores for the 3rd-level criteria to yield aggregate results at the higher levels of the criteria tree. The results comparing the aggregate input and outputs scores are shown for the mid-range scenario in Figure 6 and for the hot-dry scenario in Figure 7.

The options performed quite differently on the input and output criteria: generally, R1 (incentives to promote efficient use of agricultural water, dark green), and R2 (incentives to promote demand-side technology uptake, light green) performed well on inputs in both scenarios, while BW1 (strengthening of basin-wide water planning and governance, red) performed best on outputs.

There were also differences in performance between the mid-range and hot-dry scenarios. For example, looking at BW2 it can be seen clearly from the bar charts (in Figures 6 and 7) that it's score on both inputs and outputs is higher in the mid-range scenario. The efficient frontier is defined by BW1 and R2 in the mid-range scenario and by BW1 and R1 in the hot-dry scenario. The position of the other options relative to the frontier is unchanged between the two scenarios; BW2, U1 and U2 are dominated by BW1 in both scenarios and BW3 and U3 are dominated by R2 in the mid-range scenario and R1 in the hot-dry scenario.

2 As indicated, these weights represent only an arbitrary starting point. Weights at higher levels of the criteria tree are determined by the sum of the weight s of their sub-criteria, the approach adopted is an "equitable" assumption. However, criteria containing a larger set of sub-criteria should not necessarily be given more weight than criteria with a smaller set of sub-criteria.

Figure 6: Results of the scoring of policy options to improve water management in Yemen for the mid-range scenario

Notes: The two top-left corner pink bar-charts display the set of weights chosen for the 2nd level input and output criteria. The two top middle charts show the aggregate scores for inputs and for outputs across the eight water management adaptation policy options considered in the Yemen case study, whereas the top-right corner chart shows the same scoring but via a different visualisation. The bottom input-output chart shows the performance of each of the eight water policy options against aggregated inputs and aggregated outputs: this efficiency plot suggests that BW1 (strengthen basin-wide water planning and governance) and R2 (promoting demand-side technology uptake) are the best options.

Figure 7: Results of the scoring of policy options to improve water management in Yemen for the hot-dry scenario

Notes: The two top-left corner pink bar-charts display the set of weights chosen for the 2nd level input and output criteria. The two top middle charts show the aggregate scores for inputs and for outputs across the eight water management adaptation policy options considered in the Yemen case study, whereas the top-right corner chart shows the same scoring but via a different visualisation. The bottom input-output chart shows the performance of each of the eight water policy options against aggregated inputs and aggregated outputs: this efficiency plot suggests that in the hot-dry scenario BW1 (strengthen basin-wide water planning and governance) and R1 (promoting efficient use of agricultural water) are the best options.

Sensitivity analysis was then carried out by varying the weights on each family of criteria. In the mid-range scenario increasing the weight on environmental factors moved option R1 closer to the efficient frontier, while increasing the weight on social factors moved option U3 (urban water demand management) onto the frontier midway between R2 and BW1. Increasing the weight on the other two output criteria families did not change the composition of the efficient frontier. In the hot-dry scenario U3 once again moves onto the frontier when increased weight is given to social factors.

The analysis so far had focused on the evaluation of individual options. However, as mentioned above, there are clear synergies rising from the combination of certain options. To explore this, we created portfolios by combining the original 8 options into portfolios of two or more options. This created 255 permutations. As a first step we made the simplifying assumption that the total associated inputs required and outputs generated are simply the sum of the inputs and outputs of the individual projects. The performance of each of the portfolios is shown in Figure 8, plotting the total outputs against the total inputs.(3)

The portfolios which are of greatest interest are again those which lie on the efficient frontier, which, in this case is towards the top left-hand corner of the plot. The frontier is defined by the portfolios which generate the greatest outputs for a given level of input. It defines what is sometimes referred to as “the order of buy”. If limited resource were available, the first option that we should invest in is R2 (a portfolio of one option), which generates the greatest output for the lowest level of input. If more resources (input) are available, then the best use of these is achieved by stepping up the efficient frontier adding options to the portfolio as indicated by the labels in Figure 8. The next option to add to the portfolio is R1 (giving the portfolio R2+R1), followed by BW3, and so on. All the portfolios which lie below the efficient frontier are inefficient – this means that greater output could be achieved for the same input, or the same output for less input. The last option to be added to the portfolio moving up the efficient frontier is BW2, which, as the initial scoring showed, generates low outputs in relation to the inputs required. However, the performance of this option would be substantially improved if it was implemented in conjunction with improved governance measures such as those incorporated in option BW1. Further analysis, which took account of this synergistic effect by doubling the scores where both BW1 and BW2 are included in the portfolio, resulted in a significant shift in the efficiency frontier (Figure 9).

3 The input scores had to be inverted to allow for the portfolio analysis: a high input score in the portfolio analysis corresponds to a high input requirement, i.e. less preferred (more expensive).

Figure 8: Results of the scoring of portfolios of policy options to improve water management in Yemen and weighting of criteria at the 2nd level (Yemen case study) – based on the hot and dry scenario

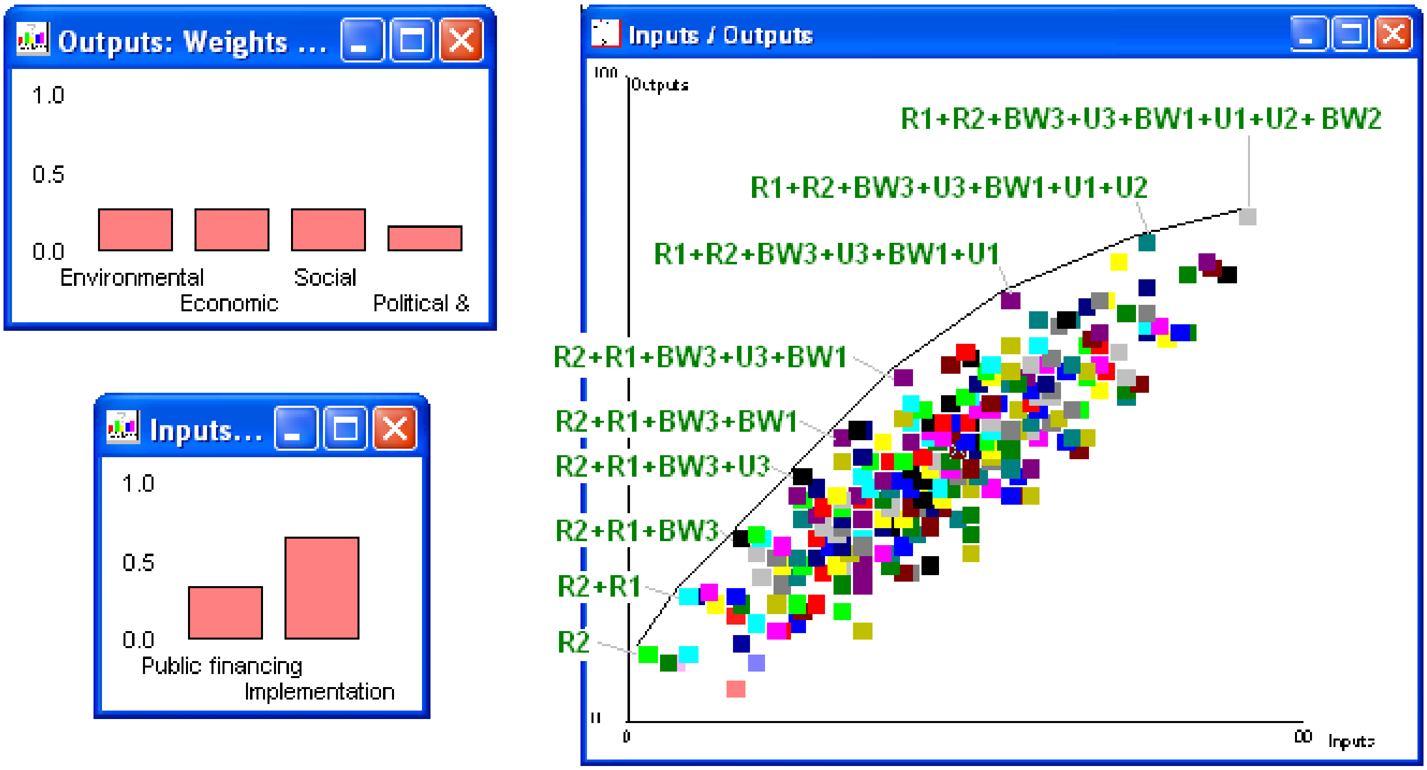
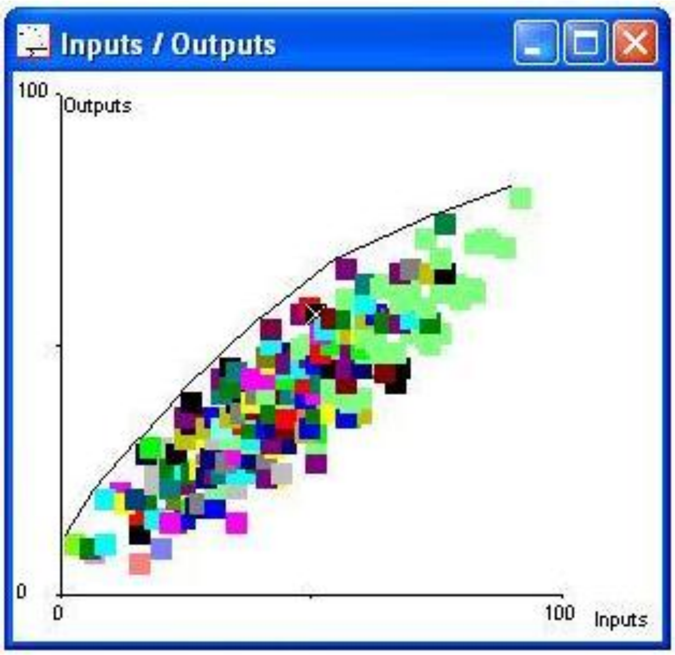
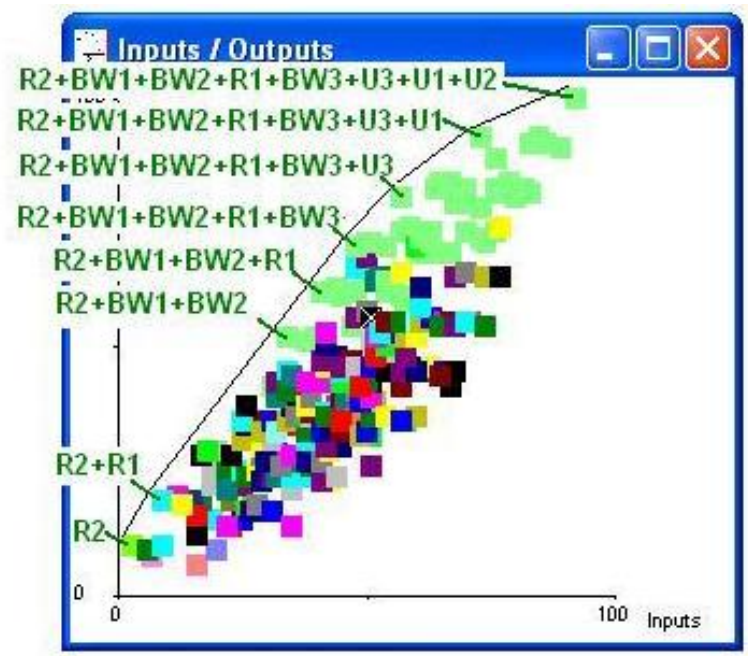


Figure 9: Results of the scoring of portfolios of policy options before and after accounting for synergistic effects between the BW1 and BW2 water adaptation options (Yemen case study)



Original plot with all portfolios incorporating BW1 and BW2 shown in pale green



Revised plot after taking account of synergy between BW1 and BW2