Excel Documentation for the Balkh River Decision Support Tool

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1 Scope of the Decision Support Tool

To provide a framework for addressing the major challenges seen in Afghanistan, an Integrated Water Resources Management tool was developed. The tool is used to understand and improve the economic and food security performance of irrigation water use patterns in Afghanistan's Balkh River Basin. The decision tool seeks to enhance the capacity of Afghan stakeholders to assess the impacts of water availability and alternative water administration measures on the level and distribution of farm incomes. The decision tool also provides a means for Afghan policy makers to study policies that have an effect on crop prices, yields and costs and their implications in income at the farm in basin level. The decision tool brings together the best available crop and farm data in order to improve farm incomes and basin-wide food security.

The decision tool is an optimization model of the agricultural sector of the Balkh Basin. It ties together the hydrologic, agronomic, economic, policy and institutional dimensions of the Basin. Results associated with policies that would affect water allocation among 14 canals are presented for five important water shortage sharing arrangements that would affect farm income and wheat food security, and it has the flexibility to examine any alternative arrangement for sharing water shortages.

The Balkh Basin has an unmet need for a method to examine the economic and food security implications of water shortages, rules for sharing water shortages in the river and policies that improve crop profitability. Water shortages and rules designed to share those shortages have important consequences, as both the level of water shortages and rules for sharing shortages affect farm income, crop production and food security. The decisions that individual farmers make in allocating land and water to individual crops is guided by the profitability and food security effects resulting from the crops that they produce. Therefore, the decision tool uses profitability to guide the decisions that are made and the results that are obtained.

The development of the optimization framework supports analysis of the effects of water shortages and water allocation arrangements. The framework describes how resource-constrained farmers are able to respond to water shortages, but it also provides useful information for explaining how farmers would react to changes in conditions. A departure in real-world behavior from the values presented in the decision tool can serve as a signal that further study is needed.

2 Excel Documentation

2.1 Overview of the Decision Tool

The decision tool is coded into Excel using formulas, and the optimization has the same structure and produces the same results as an equivalent linear programming model.

Food security is the top priority for Afghan irrigators in the Balkh basin. Food security is enforced in the spreadsheet calculations by assigning the top priority to a food-secure level of wheat production. After food security is achieved, remaining land and water if there is any left is used to maximize farm profitability for each water shortage allocation arrangement by identifying the optimal crop mix. The decision tool accounts in a consistent way for both farm income and food security by measuring the additional value gained by planting wheat in the same manner as commercially-valued crops.

Water is allocated to each canal based on the rules that govern each individual water allocation arrangement and the historical water rights of each canal. After the amount of water allocated to each canal is determined based on the water sharing arrangement chosen by the decision maker, crop mix decisions are made at the canal level for each of the canals.

Wheat is the first crop produced because farmers in the Balkh Basin typically produce wheat or other subsistence crops before bringing any commercially valued crops into production. Enough hectares of wheat are planted to meet the cereal food requirements in each canal. If there is less water allocated to a canal than sufficient to achieve a food-secure level of production, that canal will produce as much wheat as its water allocation permits.

After wheat has been planted, the decision tool uses the profitability of remaining available crops to determine the crop mix for the remaining irrigable land area. The highest valued crop is planted first. Farmers are presumed to plant as many hectares of this crop as they can, until the entire area suitable for that crop has been planted or there is no more irrigation water remaining in that canal. If irrigation water remains after the maximum number of hectares of the highest valued crop have been planted, the next highest valued crop is planted. This continues until no water remains for that canal, no positive returns can be secured from the available crops or there is no land area suitable for planting further crops.

2.2 Getting Started

The decision tool is contained in an Excel workbook. The workbook has five different types of worksheets, and all of the worksheets and cells within the worksheets are all color coded for ease of use and clarity. the color coding can be interpreted as:

Red Red colored sections contain documentation and instructions for the user on how to use the tool and interpret its results. Red cells display assumptions used by the tool.

Blue Blue colored sections allow for users to input data and change the assumptions of the tool from the data that is provided. Sheets that have a blue tab are used by the user to interact with the tool, and blue cells are for the user to insert data or change assumptions.

Yellow Yellow colored sections display the results from the tool.

Green Green colored tabs display tables that show some of the assumptions used in the analysis and the farm income and food security implications of the data used. These tables are useful for the user in the decision making process, and to learn the implications of the current data.

Black Black colored tabs are sheets that perform the calculations of the analysis.

2.3 Using the Support Tool

To use the support tool, the user will navigate from tabs of one color to the next color.

2.3.1 Step One: Read and Understand (Red Tabs)

The user should begin using the support tool by being familiar with the documentation of the tool, which is found in red tabs. The following paragraphs describe the information found in these tabs. Once the user is comfortable with the information here, the user can proceed to step two.

Documentation The 'Documentation' tab displays information about the source of the tool, including the authors and their contact information, and background information and motivation for the development of the decision support tool.

Quick Start Guide The 'Quick Start Guide' tab gives information on how to use and understand the decision tool. It explains the purpose of each worksheet and explains the color coding system found in the tabs and within each worksheet.

2.3.2 Step Two: Insert Data and Perform Policy Analysis (Blue Tabs)

In this step, the user can see the data used, and can insert any updated data that is available. The user can also create scenarios to see how results would be affected by a drought, poor yields, an increase in crop prices, etc. Changes that are made in this step instantly produce results for each of the water shortage sharing arrangements.

User Inputs The 'User Inputs' tab allows the user to insert data that better matches the changing conditions of agriculture. A great effort has been made to include the best available data in the tool, but conditions can change rapidly, and it is important to have accurate data to produce meaningful results. The data that are used in this analysis are cropland limits, crop costs and returns, cereal food requirements and lower bounds.

Cropland limits are the maximum amount of land in hectares that is appropriate for that crop in that canal. These are inserted in the blue cells under the 'Cropland Limits (Ha)' section.

Crop costs and returns are used to calculate the net return per hectare for each crop. The data used here are the price of each crop, the yield per hectare and the cost to produce each crop per hectare. Some crops produce a useful secondary product. For example, wheat produces both food wheat and straw. When a crop produces a useful secondary product, the price and yield for this secondary crop is entered under the 'Other' section from that crop. For this analysis, the price given to wheat is a constant that gives wheat a net return that is $1 above the highest valued crop.

Cereal food requirements are used to determine how much wheat should be produced to ensure a food-secure level of wheat. The data that make up this value are the kilograms of wheat per person per year required, the average number of persons per farm household, the number of farms in each canal and the percentage of the wheat harvest that is withheld for planting next year's crop.

Lower bounds are the minimum number of hectares for each crop in each canal that should be planted. This section is used to require the tool to produce crops for cultural or historical reasons before looking at the economics of producing that crop. If there are no cultural or historical reasons for planting a crop in a certain canal, these values are set to zero.

Scenario Page The 'Scenario Page' tab allows the user to change the assumptions of the tool.

Under the 'inputs' section of this tab, the user can determine the effect that changes in basin inflows, cropland limits, crop yields, crop prices and crop costs would have on the amount of water allocated to each canal, total basin income, the amount of land used in production for each crop and the total metric tons of each crop produced. When these cells are changed, we refer to this as creating a scenario. For example, a common scenario would be to see what the effect of a 10 percent drought would have in the analysis. This would be performed by changing the cell 'Basin Inflows' to 10% lower. This reduces the amount of water that flows into the basin by 10 percent. Any scenarios that are created here change all of the results on the other pages. Full results from the scenario can be found for each water shortage sharing arrangement by looking at the yellow tab labeled with that arrangement's name.

Under the 'Allocation Scheme' section, the user can insert a custom water shortage sharing arrangement in the blue cells under 'User Inserted Allocation'. The numbers that are inserted into this column represent the priority given to each canal in receiving irrigation water allocations. When one or more canals have the same value given, this means that the canals share water proportionally at the same priority level. For example, if three canals were given a priority 2, these three canals would share any water that remained after any canals that have a priority 1 receive their water. For the benefit of the user, the priority levels used for the pre-existing shortage sharing arrangements are given in the red cells in this section.

This page displays the potential regional farm income for the basin and for each canal that could be achieved given the data entered by the user and the scenario given under the 'Canal Farm Income' section.

2.3.3 Step Three: View the Results (Yellow Tabs)

In this step, the user can look at the results that are produced by the data entered into the spreadsheet and see what the effect of any scenarios input by the user would be.

The full results for each of the water shortage sharing arrangements are displayed in a tab labeled with that arrangement's name. The water that is allocated to each canal under that water shortage arrangement is shown along the top of the sheet.

Below that, in column G, the total amount of land that is irrigated in each canal is shown. Column H shows the land capacity under a full water allocation. Comparing the values in these columns shows the amount of potentially irrigable land in each canal that will not be irrigated.

Columns I through O display the net return per hectare for each crop in each canal. Columns P through V display the hectares of each crop in each canal that can potentially be produced under the given scenario and available data. These are the values that are calculated by the decision support tool.

Column W displays the farm income for each canal that can achieved from the crop mix calculated by the support tool. Columns X and Y show the average farm income produced per *paikal* and per million cubic meters of water, respectively. Column Z displays the marginal value of water, which is interpreted as the dollar value of an additional unit of water in that canal.

Columns AA through AG display the total production that can be achieved from the calculated crop mix in metric tons.

2.3.4 Step Four: View Detailed Policy Results (Green Tabs)

In this step, the user can see detailed tables that compare each of the water shortage sharing arrangements. The tabs labeled with a green color are tables that are useful for those who are using the decision support tool to determine the implications of water shortage sharing arrangements.

When new data is entered into the spreadsheet, these tables should be updated to reflect the new data. This is performed by clicking the 'Update Tables' button on either the 'Scenario Page' tab or the 'User Inputs' tab. This activates an Excel macro that automatically updates each of the tables for the user. For this to function properly, macros must be enabled in Excel. In Excel 2003, this is performed by selecting the 'Enable Macros' option from the security warning that pops up when the file is opened. In Excel 2007, this is performed by clicking 'Options...' from the Security Warning that appears across the top of the screen, and selecting 'Enable this content' from the pop-up box that opens. After this is performed, the button will properly update the tables.

Tables 1–3 display some of the data and assumptions used in the analysis.

Tables 4–5 display wheat production achieved under each water shortage sharing arrangement and two water availability scenarios, a 10 percent reduction in water flow and a 30 percent reduction in water flow. Each of the water shortage sharing arrangements performs the same under a full water supply, so this is given as the baseline for comparison. Table 4 displays the wheat production with baseline wheat yields (as entered in the 'User Inputs' tab) and table 5 displays wheat production under a 20 percent reduction in wheat yields.

Tables 6–9 display potential regional farm income by canal in millions of US dollars. Table 6 displays values with baseline crop costs and baseline crop yields (again, as entered in the 'User Inputs' tab). Table 7 displays values with baseline crop prices and crop yields reduced by 10 percent. Table 8 displays values with reduced crop prices (20 percent reduced) and baseline crop yields. Table

9 displays values with reduced crop prices (10 percent reduced) and reduced crop yields (20 percent reduced).

Table 10 displays the sensitivity of regional farm income to changes in water supply, crop price and crop costs. The results are show in elasticity form, which is interpreted as the percentage change in potential regional farm income given a 1 percent change in each parameter. These are shown for differing amounts of water availability. For example, suppose that the value under 'Upstream Priority', 'Crop Prices' and '10% Shortage' was 2.835. This would mean that under a 10 percent water shortage, when water was allocated by the upstream priority water shortage allocation arrangement, that a 1 percent increase in crop prices would increase the total basin income by just over 2.8 percent.

High values in this table signal that the support tool is sensitive to changes in this parameter. This means that the value of investing resources to secure a better data for this parameter is high and that further study may be called for.

2.3.5 Black Tabs

Black tabs are used to calculate the results of the support tool. Most users will not need to use these tabs.

2.4 How the Support Tool Calculates Crop Mixes

The decision support tool is an optimization model of the Balkh Basin that produces the same results as the equivalent linear programming model. Linear programming is a mathematical method for determining the best outcome that can be achieved given a set of requirements that must be met, including food security.

The first step that the tool takes is that it allocates the water available in the basin based on the rules of the water shortage sharing arrangements[1]. After water has been allocated to each canal in each water shortage sharing arrangement, this water is used to create a stock of land that can be irrigated. After this, crops are planted on this irrigated land.

2.4.1 Food Security: Wheat Production

Food security is the top priority for Afghan irrigators in the Balkh basin. Therefore, before the commercially-valued crop are planted, a food-secure level of wheat is planted. For each water sharing arrangement and each canal, three water availability situations are possible.

1. Enough water is allocated to the canal to produce a food-secure level of wheat and also produce commercially-valued crops. The tool will plant the number of hectares required to fulfill the cereal food requirements on the 'User Inputs' tab.
2. There is not enough water to to produce a food-secure level of wheat production. The tool will plant all of the available hectares in wheat, and there will be no left over water to produce commercially-valued crops.
3. There is no water in this canal. No wheat or crops will be produced.

Wheat is planted in each canal and for each water shortage sharing arrangement first. Then commercially-valued crops are planted.

[1]For a thorough understanding of how these different water allocations work, see the document 'Mathematical Documentation for the Balkh River Decision Support Tool', which is a companion document.

2.4.2 Commercial Crop Production

Commercially-valued crops are planted with different motivations than wheat. The planting decisions that farmers make are presumed to be guided by the profitability of planting each crop. For each canal, the following steps determine the commercially-valued planting decisions:

1. Is there irrigated land left after planting wheat? If yes continue to step 2.
2. Find the most profitable crop.
3. For this crop, two situations can be possible:
   (a) The number of hectares of irrigated land that remains is greater than or equal to the cropland limits for the crop. The tool will plant a number of hectares equal to the cropland limits for that crop.
   (b) The number of hectares of irrigated land that remains is greater than zero, but less than the cropland limits for that crop. The tool will plant all of the remaining irrigated hectares in that crop.
4. Is there irrigated land left after planting the first crop? If yes, find the second most valuable crop. Repeat step 3.
5. For remaining irrigated land after planting each crop, find the third, fourth, *et cetera* most valuable crops and continue the steps until no irrigated land remains, or no positive income can be made by planting crops.