IBMR Updating to IBMR 2008

APPENDIX B

IBMR Updating to IBMR 2008

The last version of Indus Basin Model Revised (IBMR) is based on data from 2000 (primarily the Agricultural Statistics of Pakistan and water-related data from the Water and Power Development Authority [WAPDA]) and earlier farm surveys (for example, 1976 XAES Survey of Irrigation Agriculture and the Farm Re-Survey in 1988 as part of the Water Sector Investment Planning Study [WSIPS]).

Model Structure Change: The Lateral Groundwater Flow in IBMR

Almost every aspect of hydrogeology is considered in the original IBMR structure except for lateral flow. In this study, this lateral flow was defined as the underground flow in or out of an agro-climatic zone (ACZ) due to the groundwater hydrologic gradient. Since there was no basic survey data available, this value is estimated.

Assuming that the lateral flow has a linear relationship with the change in water table, the following equation is considered:

$$D_{\text{lateral}} = kd2 \times (\Delta GD - kd1) \tag{B.1}$$

where D_{lateral} is the lateral flow, ΔGD is the monthly water table change, and $kd1$ and $kd2$ are coefficients. A pre-defined IBMR simulation was set up to solve for $kd1$ and $kd2$ for each ACZ. The purpose of this predefined simulation is to search for a set of $kd1$ and $kd2$ for different ACZs and groundwater types that makes the groundwater depth at the end of the simulation match the long-term observed value. This procedure means that the lateral flow should balance the water flow in and out of the aquifer. Since the groundwater balance is a post-calculation after the optimization in the current structure, all of the economic outcomes from IBMR will not be affected by adding $kd1$ and $kd2$.

Model Structure Change: The Refined Sugar and Sugar Cane Issue

In the original IBMR (Ahmad, Brooke, and Kutcher 1990), sugarcane will produce two different end products: SC-GUR, which is treated as refined sugar and consumed at the farm level, and SC-MILL, which is the production of sugarcane that goes into the market. SC-MILL was redefined in IBMR and the refined sugar demand for the Indus River was modeled. This section describes the details of this modification.

Using the *Pakistan Sugar Annual 2009 Gain Report* (USDA 2009), the basin-wide production, demand, and price of both sugarcane and refined sugar are available. The model uses the price and demand of refined sugar to build the demand function in IBMR. Therefore, when the model optimizes the production, it will optimize the refined sugar production. However, the cropped area and the straw yield should be computed from sugarcane. A conversion coefficient between refined sugar and sugarcane is used to achieve this purpose. The value used in the model is 0.0865, which is described in Ahmad, Brooke, and Kutcher (1990) and is also similar to the value reported by the USDA (2009). The relationship between sugarcane and refined sugar production (unit as weight) is:

$$\text{Refined Sugar} = 0.0865 \times \text{Sugarcane} \tag{B.2}$$

This coefficient is used to adjust the yield from sugarcane to refined sugar both as the unit of weight per area of land and also the straw conversion coefficient for SC-MILL. Meanwhile, since the model computes refined sugar production, SC-MILL was added as one of the consumable crops. The on-farm consumption ratio of refined sugar mentioned in Ahmad, Brooke, and Kutcher (1990) was used as the refined sugar demand for 2008–09.

Model Structure Change: Removed Variables and Equations in IBMR 2008

The tractor and private tubewell numbers in the model are considered appropriate, so further investment in tractors and private tubewells is not necessary and was therefore removed from the model. The related constraints are also removed. Draft power is 99 percent provided by tractors in Pakistan. Therefore, the provision for draft power from bullocks is removed from the model. The removal of the bullock requirement is problematic, since it is one of the meat sources in the model. The fixed-cost of bullock is much higher than cow. Under this circumstance, bullock will never be raised. Therefore, the bullocks-cow population constraint is changed to force the model to maintain a certain amount of bullocks in each ACZ. In addition, one item is added to describe the tractor cost by multiplying the price of tractor per hour per acre with the tractor power requirement of different crops, months, and ACZs.

Data Updating

Price Update

The crop prices from the "Agricultural Statistics of Pakistan (ASP) 2008–2009" (Government of Pakistan, Ministry of Food, Agriculture and Livestock 2010) are collected by region. A simple mapping check was first conducted to assign the ACZs in IBMR into the nearest region. The ratio from 2000 and 2008 ASP prices is used to update the crop price data for IBMR. The livestock prices (milk and meat) are updated with a similar procedure. Wages, protein cost, tractor cost, tubewell cost, seed cost, water cost and all other miscellaneous cost are updated based on the change in gross domestic product (GDP). A rate of 1.51 is used to update all the mentioned prices for IBMR.

Demand Update

The demand data are used to construct the demand curves in IBMR. Since the crop price has been updated, the demand should also be updated, based on the assumption that the slope of the demand curve will remain the same in 2000 and 2008. The new demands are then back calculated by fixing the slope of demand curve with the given 2008 price.

On-Farm Consumption Update

The on-farm consumption should also be updated for the new baseline. According to Ahmad, Brooke, and Kutcher (1990), the values of on-farm consumption are computed by multiplying the data in estimated total production by the proportions of produce consumed on the farm from the re-survey. Following this concept, an updated total production table for 2008 is computed first using data in the 2008 ASP. The on-farm consumption ratio is assumed to remain the same from 2000 to 2008. Using the same ratio the on-farm consumption is updated at ACZ level.

Yield Update

The observed crop yield data from the 2008 ASP were used to compare the 2000 observed yield with the IBMR 2000 baseline. Most of the crops have similar values allowing the national crop yields to be directly updated to IBMR baseline using ASP 2008 values. However, some crops—cotton, gram, orchard, and fodder—have either larger differences or have no data for updating. Therefore, the cotton yield (seed cotton) for the IBMR baseline is updated using Food and Agricultural Organization of the United Nations data. And for all other missing crops, yields are calculated using the average ratio of 2008/2000 ASP crop yields multiplied by the IBMR 2000 baseline crop yield values.

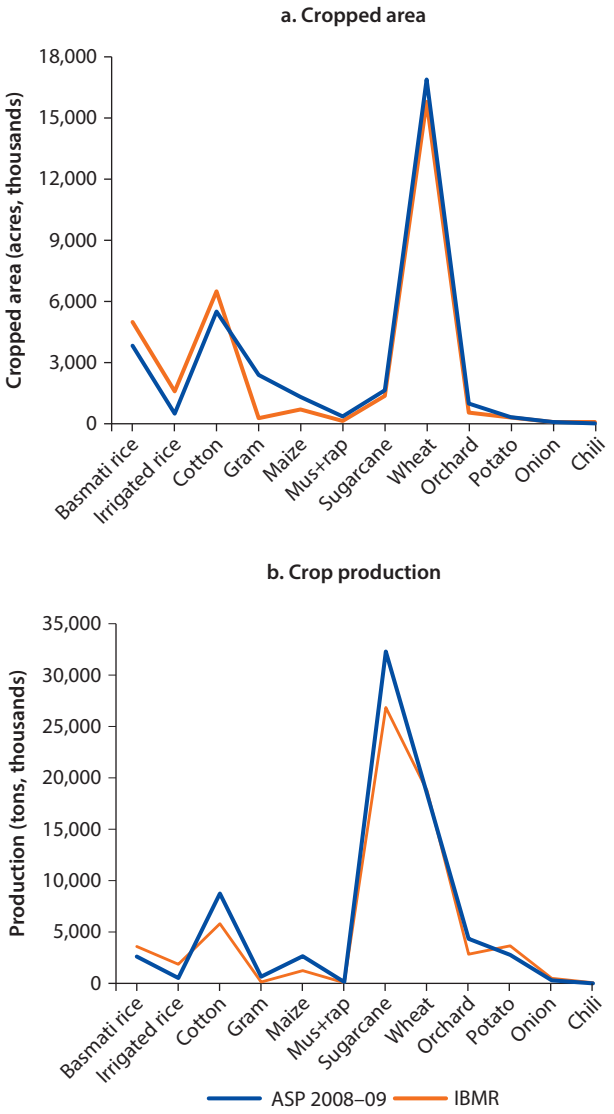
IBMR Model Diagnosis

Since IBMR is an optimization model, the results cannot be expected to match uniquely the observed values. Therefore, we do not try to validate the model with observation but rather diagnose the model to check if the crop production and area shows a similar pattern as the observed. The purpose is to understand the

performance of the model under baseline conditions as well as the difference between observations and the baseline. The primary outputs of IBMR are agricultural products; therefore, the factors checked are cropped area, crop production, and livestock production.

The observation data are all summarized from the 2008–09 ASP, and the comparisons have been done at the provincial level. Punjab and Sindh are two major provinces that rely on the irrigated network from the Indus River. The IBMR shows better results in the cropped area and production for these two provinces, as shown in figures B.1 and B.2. Almost all crops are at the same

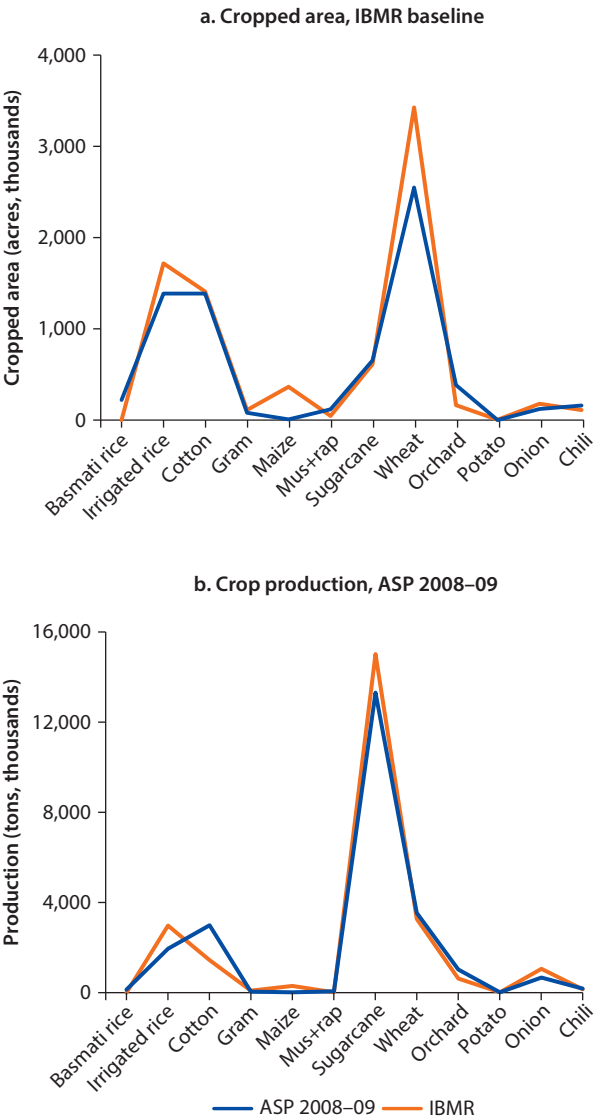
Figure B.1 Cropped Area and Production from IBMR Baseline and ASP 2008–09 in Punjab



Note: IBMR = Indus Basin Model Revised, ASP = Agricultural Statistics of Pakistan.

magnitude for the modeling result and the observation except for SC-MILL. In IBMR, we used the parameters (price, yield and consumption) of refined sugar to model this commodity. A possible reason for the underestimation might be due to the price underestimate and also government subsidies on sugarcane. The R^2 for cropped areas are 0.98 and 0.98 for Punjab and Sindh, respectively. And the R^2 for production are 0.99 and 0.99 for Punjab and Sindh, respectively. These results show that the model captures the trend of cropped area and production very well. Although the absolute values might be different, the relative cropped

Figure B.2 Cropped Area and Production from IBMR Baseline and ASP 2008–09 in Sindh

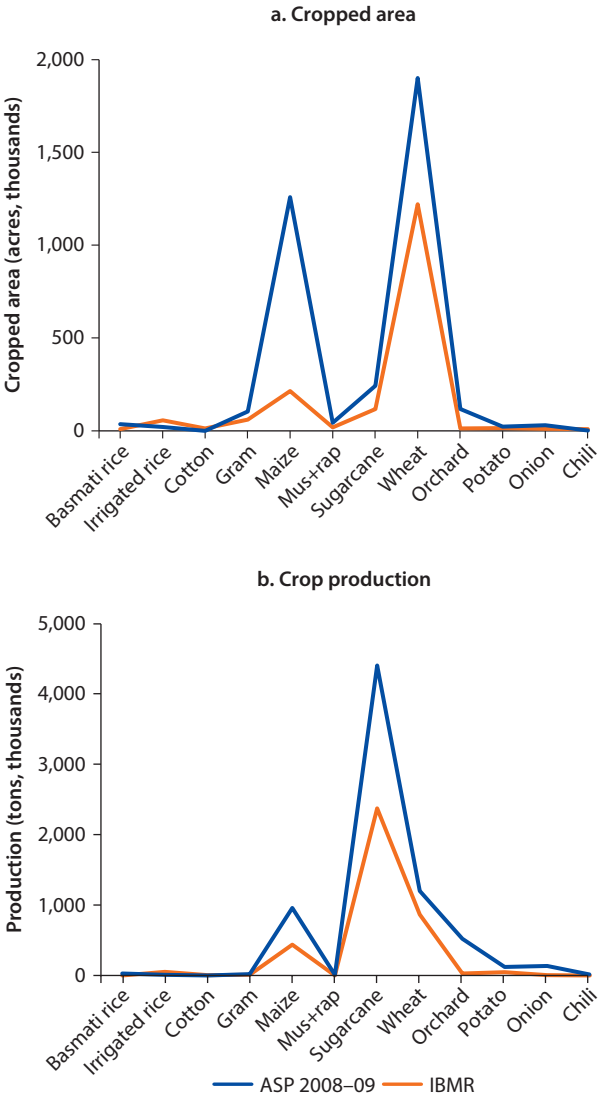


Note: IBMR = Indus Basin Model Revised, ASP = Agricultural Statistics of Pakistan.

pattern (which means the proportion of each crop in area and production) is very similar to reality.

Figures B.3 and B.4 show the cropped area and crop production in NWFP (North-West Frontier Province) and Balochistan, respectively. The modeling results are underestimated in these two provinces, which can be expected because only the irrigated area was modeled and only small portions of these two provinces are covered by the irrigated network in reality. Ahmad, Brooke, and Kutcher (1990) used a coefficient of determination (R^2) to test if the model can

Figure B.3 Cropped Area and Production from IBMR Baseline and ASP 2008–09 in NWFP

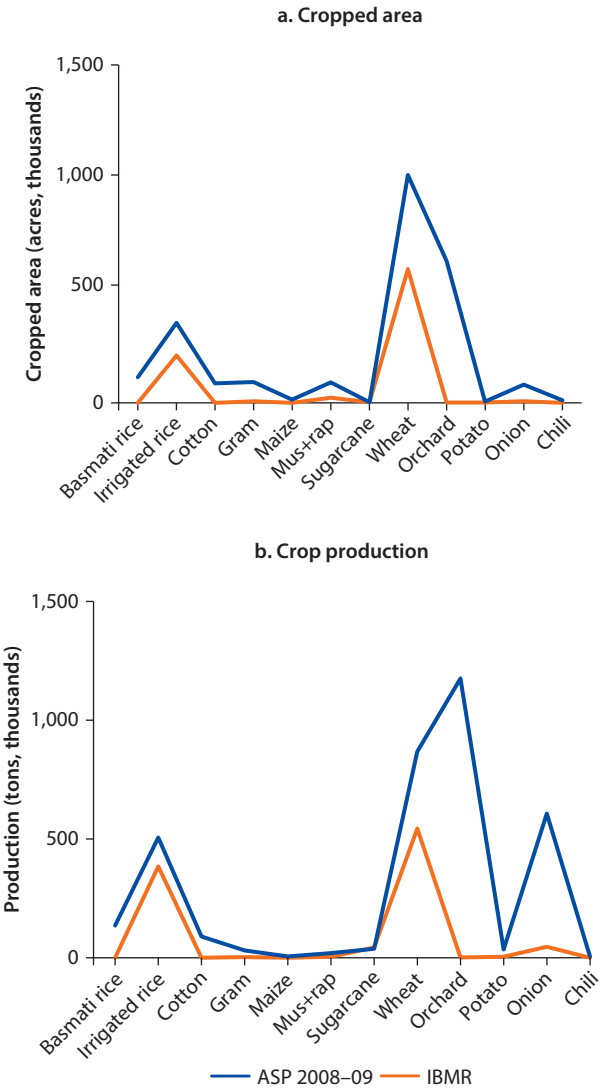


Note: IBMR = Indus Basin Model Revised, ASP = Agricultural Statistics of Pakistan, NWFP = North-West Frontier Province.

at least capture the trend of cropped area and production. The R^2 for cropped areas are 0.90 and 0.83 for NWFP and Balochistan, respectively. And the R^2 for crop production are 0.98 and 0.41 for NWFP and Balochistan, respectively. Balochistan shows the largest differences between modeling results and observation. But since Balochistan only represents a very small portion of the entire Indus River, the results will not significantly affect the basinwide outcome.

Table B.1 shows the results of modeling livestock numbers compared to the ASP data. (Only Sindh province has 2008–09 data available, other provinces

Figure B.4 Cropped Area and Production from IBMR Baseline and ASP 2008–09 in Balochistan



Note: IBMR = Indus Basin Model Revised, ASP = Agricultural Statistics of Pakistan.

Table B.1 Livestock Comparison between IBMR 2008 and ASP 2008–09
animals, thousands

		Cow	*Bullocks*	*Cattle*	*Buffalo*
NWFP	IBMR	94	47	141	429
	ASP 2006			5968	1928
Punjab	IBMR	3074	1537	4611	6178
	ASP 2006			14412	17747
Sindh	IBMR	1602	801	2404	4117
	ASP 2008–09			6925	7340
Balochistan	IBMR	104	52	156	0
	ASP 2008			2254	320

Note: IBMR = Indus Basin Model Revised, ASP = Agricultural Statistics of Pakistan, NWFP = North-West Frontier Province.

have only 2006 data.) Generally, livestock is underestimated. A major reason is that much of the livestock production is in the non-irrigated areas and is not modeled in IBMR. Thus, the modeled livestock numbers are only half of the ASP data. The other possible reason is that in the model bullocks were removed and the ratio between cow and bullock was fixed. This modification might also affect the number of cows and bullocks in the model since the bullock population is capped by the cow population.

This appendix provides some diagnosis of the IBMR baseline run compared to observed data. Although the modeling results do not perfectly match the ASP data, they still provide a reasonable framework to assess the irrigated agro-activities in the Indus River Basin.

References

Ahmad, M., A. Brooke, and G. P. Kutcher. 1990. *Guide to the Indus Basin Model Revised*. Washington, DC: World Bank.

Government of Pakistan, Ministry of Food, Agriculture, and Livestock. 2010. "Agricultural Statistics of Pakistan 2008–2009." Islamabad, Pakistan.

USDA (U.S. Department of Agriculture). 2009. "Pakistan Sugar Annual 2009 Gain Report." USDA Foreign Agricultural Service-PK9005, U.S. Department of Agriculture, Washington, DC.