5.3 Models Used to Estimate Impact of Introducing Technologies in Countries Other than Origin of Experimental Data

5.3.1 INTSORMIL Technology

Potential West Africa (WA) regional impact of improved INTSORMIL varieties in Senegal, Mali and Burkina Faso was estimated with the ASM and SPEC models for Mali. The SPEC models estimated the economic impact of the sorghum variety introduction at the national level only. The process was repeated in Senegal and Burkina Faso with a SPEC model developed for each of those countries for evaluating the national economic impact of introducing the improved INTSORMIL varieties.

5.3.2 Peanut CRSP Technology

Similar to the INTSORMIL case study, potential economic impact of adopting improved Peanut CRSP varieties in Mali and in Burkina Faso was carried out with a SPEC model. First, the model estimated the economic impact of introduction of the peanut varieties developed in Senegal. Estimates were made only at the national level. This process was repeated for Mali and Burkina Faso using extrapolated crop yields and adjusted hectares of crop plantings from introducing the improved Peanut CRSP technology into Mali and Burkina Faso.

5.4 Spatial Characterization of Crops and Yield Estimation

5.4.1 Historic Sorghum and Peanut Yields

Sorghum yields in Burkina Faso and Senegal and peanut yields in Burkina Faso and Mali were simulated using the EPIC biophysical crop simulation model. Sorghum and peanut plant growth was modeled under a wide range of soil, climatic, and geographic categories. A description of the crop modeling process is given in the crop modeling Section 4 of this report. Historic traditional and simulated improved sorghum yields are provided in Table 5.1.1. Historic traditional and simulated improved peanut yields are provided in Table 5.1.2.

5.4.2 Spatial Yield Variation

Yield information obtained from the EPIC biophysical simulations should approximate reported yields from politically defined areas that span agroecological zones. To obtain EPIC simulated yields that correspond to yields reported in the official statistics requires weighting yields by hectarage, soils, and climates observed in each political district.

The Almanac Characterization Tool (ACT) was used to achieve the required synthesis. ACT defines polygons that represent each of the modeled soil types within each political entity studied. It then defines the polygons more precisely by accounting for the climatic, physical and human geographic conditions observed. The yield assigned to each polygon is then weighted by the hectares each polygon represents. The
weighted yields are then summed to produce the expected yield for the political area under analysis. Equation 5.4.2-1 describes the weighting process for a political district. This process is discussed in detail in Section 4 of this report.

\[ \text{Equation 5.4.2-1} \]
\[ Y_{oij} = \sum_{n=1}^{l} Y_{olij} \times H_{ol} \]
\[ Y_{oij} = \text{The Epic yield for subregion } o, \text{ agronomic practice } i, \text{ and crop } j \]
\[ Y_{olij} = \text{Epic yield for subregion } o, \text{ polygon } l, \text{ agronomic practice } i, \text{ and crop } j \]
\[ H_{ol} = \text{Hectares in sub – region } o, \text{ represented by polygon } l \]

The numeric yields produced by the EPIC model and aggregated with the ACT program are not used directly in the SPEC analysis. Rather the percentage change from the traditional yield under the relevant agronomic practice is calculated and used to adjust the base yields in the ASM or the historic traditional yields in the SPEC model. The ASM thus uses the subnational regional yields from equation 5.4.2-1 in its analysis. The SPEC model uses a national yield that is the hectare weighted average of the subnational regional yields (equation 5.4.2-2). ASM contains accounting equations that aggregates across regions and commodities to derive national estimates of consumers surplus, producers surplus, home consumption costs, foreign surplus and total economic surplus. In the SPEC analysis these measures of economic welfare changes are computed directly for the national level.

To provide a comparison between modeled and reported data, the EPIC model had to reflect yield changes of millet and sorghum combined in Senegal since millet and sorghum yields are reported jointly in official Senegal agricultural statistics. Two scenarios were considered for Senegal. In one scenario, hectarage allocated to the improved sorghum was 10 percent of the total area planted to sorghum. In the other scenario it was assumed that 40 percent of the sorghum hectarage was planted to improved varieties.

\[ \text{Equation 5.4.2-2} \]
\[ IY_{oij} = ( ((EY_{oij} - Y_{ob}) / Y_{ob}) + 1 ) \times B_{oij} \]
\[ o = \text{subnational ~ region} \]
\[ i = \text{the agronomic practice} \]
\[ j = \text{the crop variety} \]
\[ IY_{oij} = \text{Improved yield for agronomic practice } j \text{ for crop } i \]
\[ EY_{oij} = \text{Epic Yield for agronomic practice } j \text{ for crop } i \]
\[ Y_{ob} = \text{The low fertility traditional yield for crop } i \]
\[ B_{oij} = \text{The traditional yield for agronomic practice } j \text{ for crop } i \]
5.4.3 Estimation of Crop Hectarage

Changes in crop yield can potentially lead to changes in hectares planted to that crop and alternative crops. The SPEC approach reflects changes in land allocation due to improvements in crop yield by capturing historic relationships between planted hectares of a crop, expected yield, and other independent variables. For the SPEC model to reflect changes in land allocation due to improvements in crop yield it was necessary to estimate historic relationships between planted hectares of a crop, expected yield and other independent variables.

The estimation of peanut, millet, and sorghum hectarage with various technology innovations was based on evaluation of a set of independent variables estimated for each crop using the “Seemingly Unrelated Regression Method” (Zellner). Independent variables included historic data on crop price, crop yields, precipitation, fertilizer use, agriculture labor, fertilizer price and time. Prices were indexed for inflation. Logarithmic transformations were made to the original data set and crop hectares were expressed as a function of the previous year’s values for the independent variables.

Tables 5.4.3.1 to 5.4.3.3 provide the estimated regression coefficients of the equations for planted hectares for each commodity respectively in Burkina Faso, Senegal and Mali. Millet and sorghum were treated as one commodity in Senegal due to that country’s method of gathering and reporting combined data for these commodities. In 1997 sorghum hectares represented 15% of the total millet-sorghum hectares planted in Senegal. The estimated regression coefficients along with the adjusted R² values and t-value statistics (shown in the parenthesis) are reported in each table. The regression coefficients indicate the change in planted hectarage for a crop associated with a one-unit change in the independent variables included in the regression.

Table 5.4.3.4 describes the percent difference in estimated hectares and observed national hectares by commodity for each country. Five regressions provided hectarage estimates within 4 to 7% of those reported in the base year. The remaining three regressions provided estimates greater than 20% of the reported base hectarage for peanuts in Senegal and millet in Burkina Faso and Mali.

Allocation of hectarage to sorghum, peanut, and millet production was performed using yields of improved varieties. Adjustments in the sorghum, millet, or peanut hectarage were proportionately added to or deleted from hectares of other major crops to maintain national cropland resource balance. Base production of sorghum, millet, and peanut is base hectarage multiplied by the national base yield for each crop. Production from introducing new varieties is improved variety yields multiplied by estimated hectarage allocations for each crop. Other major crops are assumed to maintain base yield levels in the estimation of production as new varieties of sorghum, millet, or peanut are introduced.
Table 5.4.3.1 Estimated parameters for Burkina Faso sorghum, millet, and groundnut hectare equations, 1966 to 1991

<table>
<thead>
<tr>
<th>Crop</th>
<th>$b_0$ (R²)</th>
<th>$b_1$</th>
<th>$b_2$</th>
<th>$b_3$</th>
<th>$b_4$</th>
<th>$b_5$</th>
<th>$b_6$</th>
<th>$b_7$</th>
<th>$b_8$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorgh</td>
<td>13.821 (0.724)</td>
<td>0.077</td>
<td>-</td>
<td>0.201</td>
<td>-0.1408</td>
<td>-0.0394</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mill.</td>
<td>13.570 (0.503)</td>
<td>0.067</td>
<td>0.3290</td>
<td>-</td>
<td>-</td>
<td>-0.036</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gr.</td>
<td>14.562 (0.201)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.081</td>
<td>-0.457</td>
<td>0.101</td>
</tr>
</tbody>
</table>

* Sorgh = sorghum, Mill. = millet, and Gr. = Peanuts,
1 Significant at the 10% confidence interval, 2 significant at the 5% confidence interval, 3 Significant at the 1% confidence interval

$^0 = \text{Constant term}$

$^1 = \text{Lagged logged millet price}$

$^2 = \text{Lagged logged millet yield}$

$^3 = \text{Lagged logged sorghum yield}$

$^4 = \text{Lagged logged peanut yield}$

$^5 = \text{Lagged logged fertilizer value}$

$^6 = \text{Lagged logged peanut to sorghum yield}$

$^7 = \text{Lagged logged precipitation}$

$^8 = \text{logged time period t}$

Sources:
International Monetary Fund Annual Report, 1998,
FAOSTAT data base
USDA international database, Mann Library, Cornell University
Table 5.4.3.2  Estimated parameters for Senegal sorghum-millet, and groundnut hectare equations, 1966 to 1996

<table>
<thead>
<tr>
<th>Crop Ha. *</th>
<th>$a$</th>
<th>$b$</th>
<th>$c$</th>
<th>$d$</th>
<th>$e$</th>
<th>$f$</th>
<th>$g$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill-Sorgh</td>
<td>13.146$^1$</td>
<td>0.534</td>
<td>-0.236$^1$</td>
<td>0.21$^3$</td>
<td>-</td>
<td>0.009</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(0.42)</td>
<td>(27.2)</td>
<td>(1.09)</td>
<td>(-2.56)</td>
<td>(4.24)</td>
<td>(1.14)</td>
<td></td>
</tr>
<tr>
<td>Gr.</td>
<td>11.599$^3$</td>
<td>0.545$^3$</td>
<td>0.186$^1$</td>
<td>-0.30$^3$</td>
<td>-0.038$^3$</td>
<td>-</td>
<td>0.545$^3$</td>
</tr>
<tr>
<td></td>
<td>(0.74)</td>
<td>(44.53)</td>
<td>(-2.96)</td>
<td>(-1.42)</td>
<td>(-5.39)</td>
<td>(-1.76)</td>
<td>(5.21)</td>
</tr>
</tbody>
</table>

* Mill. = millet, Sorgh = sorghum, and Gr. = s,
1 Significant at the 10% confidence interval, 2 significant at the 5% confidence interval, 3 Significant at the 1% confidence interval

Sources:
FAOSTAT data base
USDA international database, Mann Library, Cornell University
International Monetary Fund Annual Report, 1998
Institut Sénégalais De Recherches Agricoles Unité De Recherche Politique Agricole et Socio-Economie (ISRA)
Ministere de L’économie, Des Finances et du Plan, Direction de la Prévision et de la Statistique
Table 5.4.3.3 Estimated parameters for Mali sorghum, millet, and peanut hectare equations, 1966 to 1991

<table>
<thead>
<tr>
<th>Crop Ha.*</th>
<th>b_0 (T-stat)</th>
<th>b_1</th>
<th>b_2</th>
<th>b_3</th>
<th>b_4</th>
<th>b_5</th>
<th>b_6</th>
<th>b_7</th>
<th>b_8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorgh</td>
<td>12.866</td>
<td>0.643</td>
<td>-</td>
<td>-0.044</td>
<td>-0.020</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.679</td>
</tr>
<tr>
<td></td>
<td>(0.39)</td>
<td>(58.60)</td>
<td>(3.59)</td>
<td>(3.50)</td>
<td>(-1.15)</td>
<td></td>
<td></td>
<td></td>
<td>(-1.45)</td>
</tr>
<tr>
<td>Mill.</td>
<td>13.290</td>
<td>0.768</td>
<td>0.647</td>
<td>-</td>
<td>-</td>
<td>-0.018</td>
<td>-</td>
<td>-</td>
<td>-0.277</td>
</tr>
<tr>
<td></td>
<td>(0.73)</td>
<td>(90.17)</td>
<td>(5.915)</td>
<td>(-5.865)</td>
<td>(-1.984)</td>
<td></td>
<td></td>
<td></td>
<td>(-0.85)</td>
</tr>
<tr>
<td>Gr.</td>
<td>11.702</td>
<td>-0.763</td>
<td>-0.536</td>
<td>-</td>
<td>-</td>
<td>-1.401</td>
<td>1.401</td>
<td>0.060</td>
<td>-1.262</td>
</tr>
<tr>
<td></td>
<td>(0.50)</td>
<td>(44.53)</td>
<td>(-2.96)</td>
<td>(-1.42)</td>
<td>(3.042)</td>
<td>(2.54)</td>
<td></td>
<td></td>
<td>(-1.95)</td>
</tr>
</tbody>
</table>

* Sorgh = sorghum, Mill. = millet, and Gr. = Peanuts,
1 Significant at the 10% confidence interval, 2 significant at the 5% confidence interval, 3 Significant at the 1% confidence interval

b_0 = Constant term
b_1 = Lagged logged millet price
b_2 = Lagged logged cotton price
b_3 = Lagged logged cotton price squared
b_4 = Lagged logged ratio of sorghum to groundnut yield
b_5 = Lagged logged ratio of millet to groundnut yield
b_6 = Lagged logged groundnut price
b_7 = Lagged logged ratio of groundnut to millet yield
b_8 = Lagged logged fertilizer to agriculture labor ratio

Sources:
Institut D'économie Rurale (IER)
International Monetary Fund Annual Report, 1998,
FAOSTAT data base
USDA international database, Mann Library, Cornell University

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Table 5.4.3.4: Percent difference in estimated and observed national hectares in production by commodity

<table>
<thead>
<tr>
<th>Country</th>
<th>Peanuts</th>
<th>Millet</th>
<th>Sorghum</th>
<th>Millet/Sorghum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burkina Faso</td>
<td>-7.0</td>
<td>21.0</td>
<td>7.0</td>
<td>--</td>
</tr>
<tr>
<td>Mali</td>
<td>5.9</td>
<td>34.7</td>
<td>-3.6</td>
<td>--</td>
</tr>
<tr>
<td>Senegal</td>
<td>20.9</td>
<td>--</td>
<td>--</td>
<td>5.5</td>
</tr>
</tbody>
</table>
5.4.4 Price Change Estimation

In the SPEC model price changes are estimated by determining the market clearing price for a given change in production of each commodity. This is determined by dividing the percentage change in production by the demand elasticity coefficient. This ratio is then multiplied by the base price and added to the base price as shown in equation 5.4.4-1.

**Equation 5.4.4-1**

\[
IP_j = \left( \left( \frac{Q_{1j} - Q_{oj}}{Q_{oj}} \right) / h_j \right) + 1 \right) \times BP_j
\]

- **IP** \(_j\) = Price of commodity \(j\) with the introduction of the improved variety
- **Q\(_{1j}\)** = Quantity produced under the new hectares and yields associated with improved variety \(j\).
- **Q\(_{oj}\)** = Quantity produced under the base hectares and yields associated with traditional variety \(j\).
- **h\(_j\)** = Demand elasticity for commodity \(j\)
- **BP** \(_j\) = Base price for commodity \(j\)

5.5 Welfare Estimation and Results

The shift in production is assumed to be a parallel shift and the demand elasticity coefficient is assumed to be constant for each commodity. Consumer surplus is estimated for sorghum, millet, and peanut in Burkina Faso and Mali. In Senegal consumer surplus is estimated for millet/sorghum and peanut.

Estimation of consumer surplus is calculated using the closed economic surplus model of Alston and Purdey, where the change in the area under the demand curve above the price line before and after the innovation is calculated. Producer surplus is calculated by taking the difference between total revenues and total costs in the SPEC model.

5.5.1 Sorghum

5.5.1.1 Burkina Faso

Sorghum production increased by an estimated 32 thousand tons (0.29%) for N’tenimissa and 25 thousand tons (2.28%) for Seguetana when these varieties are introduced into Brukina Faso. Price declined by 0.36% for the N’tenimissa and 2.85% for the Seguetana scenarios. Annual consumer surplus was increased by 42 million fcfa with the introduction of N’tenimissa and 299 million with Seguetana. Producer surplus also increased due to the reallocation of land to sorghum, peanuts, and millet. Home consumption costs increased for both varieties. The increase in price of other crops as land reallocation caused a decline in production resulted in a subsequent increase in cost of food stuffs for home consumption. Total national welfare increased 3.198 billion fcfa for the N’tenimissa scenario and 1.991 billion fcfa for the Seguetana scenario (Table 5.5.1.1).