specialist to pick up fecal samples of livestock (cattle, sheep, and goats) in remote regions and predict dietary crude protein and digestible organic matter of animals in question. By spatially sampling feces using a GPS unit, a profile of nutrition of the animals can be built over a growing season or year and those values fed into the animal production models. The system is based on drying the sample, grinding through a 1-mm sieve and then scanning with a near-infrared reflectance spectrophotometer. Our laboratory or regional labs established throughout the world can turn around samples in 10 days from almost any part of the world.

By far the most critical cultural operations for crops are the planting and maturity dates. These can vary with soil conditions and elevation even in relatively small areas. Harvest dates, when available, are used as proxies for crop maturity. Some of the models like the EPIC model have been modified to accept “heat unit scheduling” to refine the planting dates and schedule tillage and fertilizer applications. Using these algorithms, inputs like minimum soil temperature, soil moisture, and percentage of the growing season are used to determine planting dates and operations.

Critical crop parameters like maturity classes of local or unknown varieties are frequently estimated by using historical information of planting and harvest dates. The maturity parameters are then adjusted to reproduce the historical timing patterns. These coefficients in the form of accumulated heat units are then returned to the parameter file for use in future runs when addressing changes in weather, elevations, and location that are assumed to be using the same genetic varieties.

In general, the models themselves are frequently used to verify, reject, and refine estimates of “soft input data”. Iterations of model runs will reveal many refinements needed in the inputs shown as inappropriate outputs and estimates. A person familiar with the model can generally trace these bad estimates to the sources in the inputs.

### 6.10 Improved methods for risk assessment at farm and national levels

Most risk in agriculture stems from the uncertainty in the biological and environmental variability associated with agricultural production, as well as economic uncertainty due to price fluctuations in inputs and demand. Providing point or average estimates of the economic impact of the introduction of a technology cannot provide the decision-maker with any information regarding the risk or uncertainty associated with the adoption of a new technology.

At the farm level, uncertainty was incorporated into the analysis by the use of the simulation tool Farm Level Income and Policy Simulation Model (FLIPSIM) linked with cropping and grazingland biophysical models. Simulation is a means of estimating the economic impact of a new technology under uncertainty by reproducing random events that are statistically equivalent to the probabilistic outcomes that occur in the system being modeled. The descriptive nature of a simulation model allows experiments to be performed on complex systems under conditions of uncertainty. Calculating the statistical variability provides an estimate of risk or uncertainty. The simulation approach is used to compare different technologies to determine which provides the highest probability of achieving different targets. It also allows a decision maker to compare two technologies to determine which provides the least amount of risk. Use of this modeling method provides insights into the impact on producers of introducing new technologies at the farm level that were not captured by simply comparing the average change in the yields, cash costs, farm income, real net worth, and net present value.
At the national level, uncertainty was incorporated into the agricultural sector model by calculating the optimal allocation of resources under different expected climatic states of nature and risk aversion preferences. The expected long-run welfare implications of a new technology is reflected in the weighted average of the probabilities of each state of nature. Use of this approach again provided insights that were not captured by the static model. One insight in particular was the gain in producer surplus observed under the stochastic scenario that was not captured under the deterministic analysis.

6.11 Verification of Models Relative to Measured Data and Conditions

Verification of the output of economic models required comparison of the base runs of the models with the observed yields and land allocation at subregion and national levels noted in statistical data for the starting year. If the percentage difference in the base model output was within a range considered acceptable, generally less than 10% of the observed data, the model was considered to be correctly calibrated.

Verification of biophysical models can be accomplished by locating actual field data with accompanying information on such things as soils, weather, animal attributes, etc., and running the models to determine if yield response (crops, forage, livestock) are tracking observed data. Another method to confirm yields of widely reported crop species is to develop a spatial stratification of soils and weather, generate yields within each resulting simulation environment (polygon), and produce an area-weighted yield corresponding to administrative reporting districts.

We felt that the models were performing well if predicted yields were within 15% of reported yields across 80% of the reporting districts for each crop. If deviations occurred, we had to explain the cause in terms of markets and home consumption, or we had to reparameterize the biophysical models. Other forms of verification involved knowledgeable experts reviewing output to determine if the input data and the yield responses are within the domain of acceptable response for a given biophysical and managerial environment. In the case of hydrologic response, it is critical to have access to streamflow gauge data and sediment loading data to both calibrate and verify projections at the watershed scale. Normally the up-stream gauges are used to calibrate the model and the outflow basin gauge used to verify model accuracy.

6.12 Status of Modeling Environmental and Natural Resources Impact of New Technology

The overall state of the art in modeling environmental and NRM consequences of technology innovations is paced by the state of knowledge about plant-animal-natural resources interactions and behavior at the fundamental level. Researchers and NRM managers at all levels are looking for better indicators of the status of natural resources and the time course of changes in NRM characteristics as a function of their use in farming over time. The EPIC model and several hydrologic models have been used in IMPACT as tools that are available and that seem to be representative of the state of the art. Our group does not aspire to engage in the badly needed fundamental research to define the needed indicators and underlying biology to improve such models. However, we do aspire in our future work to develop linkages with those who do this kind of research and to apply the results to improved environmental models that describe the overall state of the ecosystem as a function of agricultural operations to provide improved food security.