# ENERGY ANALYSIS OF AGRICULTURAL PRODUCTION SYSTEMS

Energy is embodied in all of the equipment, inputs, and products of agriculture. Agriculture both uses and supplies energy in the form of bioenergy and food. The amount of energy used in agriculture has grown substantially, and currently, the agri-food chain accounts for 30 percent of the total energy used around the world [1]. Sustainable agricultural production requires the optimization of land use, energy efficiency, end of the use of fossil energy sources, and minimization of environmental impacts. Current agricultural systems are heavily dependent on fossil energy resources. Energy analysis allows the quantification of the amounts of energy used for agricultural production and can be used to optimize energy consumption and increase energy efficiency to move agriculture closer towards sustainability.

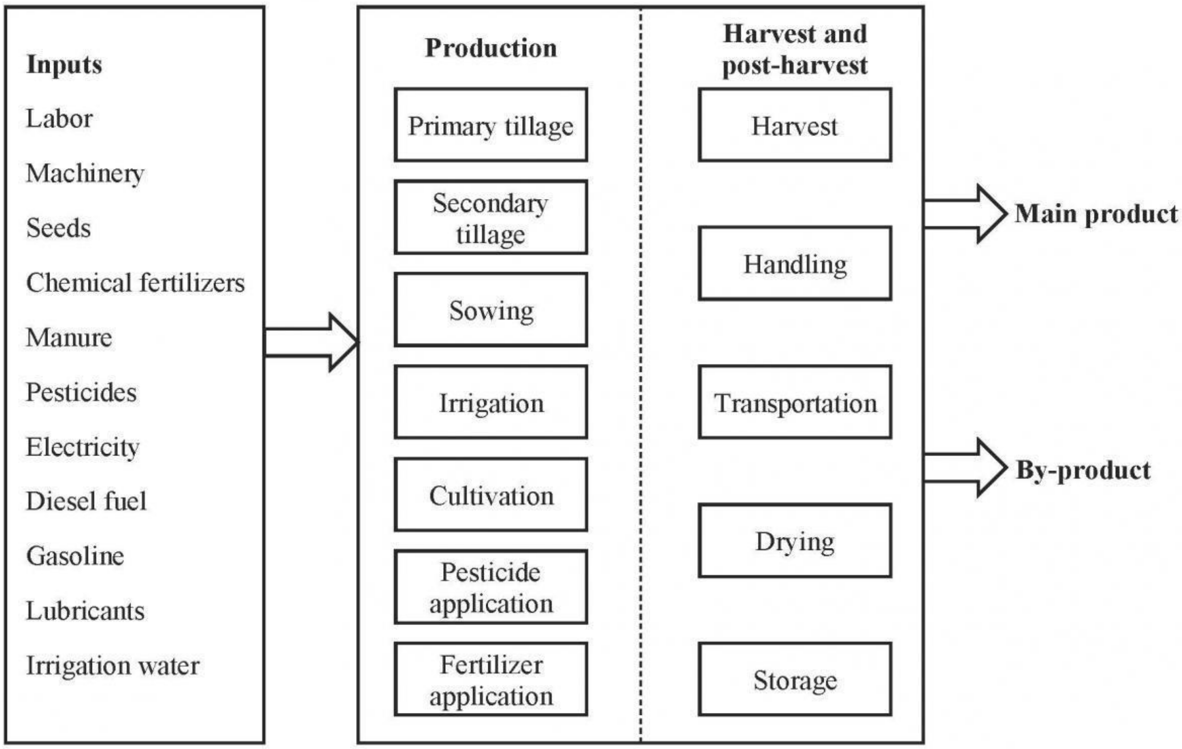
**Methodology of Energy Analysis in Production Agriculture**

***Step 1: Defining scope and functional unit***

The scope of energy analysis depends on the objective. Usually, the scope of energy analysis in production agriculture is confined to activities required for agricultural production, from the manufacture of inputs, energy used for production, and energy for storage of the products before they are sold (Figure 1). Energy consumption for different activities within an agricultural production system are usually defined in relation to the functional unit. Thus, the functional unit is usually expressed in terms of mass (e.g., 1 ton), area (e.g., 1 acre), or economic value (e.g., $1000 revenue). For estimating the overall energy requirements for different activities related to an agricultural production system, the direct inputs to all the activities (Figure 1) are identified. However, agricultural operations vary in their energy use based on the details of the production system. For example, a zero-till rain-fed corn production system may have much different energy use balance than an irrigated tillage system.

***Step 2: Quantifying inputs to different activities of the agricultural production system***

In energy analysis, energy and material requirements are estimated for the manufacture and transportation of inputs used for the different agricultural activities considered in the analysis. This allows the quantification of the amount of energy used for production, harvest, and post-harvest logistics operations in terms of the same functional unit. Figure 1 shows the energy using activities that must be accounted for in energy analysis for crop production agriculture. Inputs for crop production, harvest, and post-harvest logistics operations may include seeds, chemical fertilizers (nitrogen, phosphate, potassium, and sulphur), pesticides (herbicides, fungicides, and insecticides), diesel fuel, lubricants, electricity, manure, irrigation water, labor, and machinery. Some operations require special machines and equipment, such as tractors, cultivators, spreaders, sprayers, harvesters, irrigation systems, transportation equipment, and dryers, as well as facilities, such as transportation terminals and storage facilities for agricultural products and by-products.




**Step 3: Converting the physical inputs and outputs to energy**

The physical inputs and outputs of different agricultural operations need to be converted to common energy units using energy equivalent coefficients (Table 1). The energy equivalent coefficient of an input is defined as the sum of the energy consumed during the production of the input and the energy used for transportation of the input to the end user or local market. The energy used for production and transportation logistics varies based on differences in technology in different regions and countries, energy consumption for the specific production process used, and transportation distance and technology. So, the energy equivalent coefficient of an input varies substantially as a function of location. Energy equivalent coefficients for agricultural inputs are presented in Table 1.

***Step 4: Interpreting the results of energy analysis***

As a final step, the energy ratio (Eq. 3) is determined in which "energy output" (i.e., stored chemical energy of the product) is assessed relative to "total energy input" [15]. The other indicator is energy productivity, which quantifies the production rate per unit energy use (Eq. 4). The net energy return is the absolute difference between “energy output” and “total energy input” (Eq. 5).

$$\text{Energy productivity [lb/BTU]} = \frac{\text{Production mass [lb]}}{\text{Total energy input [BTU]}}$$

Energy productivity, kg/kJ = Production mass, kg /Total energy input, kJ