Expert assessment of agrotechnologies with positioning key components

N N Krupina
Saint-Petersburg State Agrarian University, Faculty Rural Development and Management, 2 Petersburg highway, St. Petersburg, Pushkin, 196601, Russia
E-mail Krupina_n17@mail.ru

Abstract. Fuzzy expert assessment of the current state and prospects for changing technologies is based on knowledge of the subject area of research, understanding of foresight priorities, and the choice of components whose loss leads to maximum damage to functionality. The relevance of the structural analysis of technologies is justified, the basic components and their weights are highlighted (by the example of poultry farming), and the positions of agricultural technologies are defined in the coordinates «level of innovation – impact on cost» are determined. Basic components of the technology are input and output flows; volume-space parameters of objects; technological mode of operations, materials, reagents, biologics; machines, equipment, vehicles; means of automation and computerization of quality control and management; staff competencies. A graphic technique of technology choice in the conditions of market uncertainty, constant risk and instability of agricultural production conditions is considered. The results of the study can serve as a working tool to facilitate the construction of the expert’s chain of reasoning.

Keywords: input and output flows, technological mode, spatial parameters, machines and equipment, materials, reagents, biologics, technological innovations, costs, technological analysis.

1. Introduction
A fuzzy expert system uses the representation of knowledge in the form of linguistic variables, so the expert should have a detailed idea of the essential nature, value, orientation and degree of influence of technology components on the results of activities [1]. It is important to identify the components, the loss of which leads to the maximum loss of functionality, and then clearly connect the linguistic values of the ratings with specific numbers on the rating scale. In addition, the structuring of the object allows you to build more reliable aggregated assessments and develop fairly universal assessment programs. In fuzzy expertise, knowledge of the research subject area and understanding of foresight priorities are especially relevant, which inevitably increases the importance of technology expertise [2].

The author’s goal is the development of theoretical ideas about the structure of agricultural technologies and the identification of components that form specific relationships and impacts, which can be useful in the work of specialists to achieve a coordinated aggregate expert assessment.

2. Informal statement of the problem
Let us formulate the basic concept: agricultural technology is a highly organized system of means of production and staff competencies in conjunction with consciously implemented physical, mechanical and biological-chemical methods of exposure when growing and/or processing specific natural («living») labor objects (land, plants, animals, fish, birds, bees) reproduced systematically and
sequentially in time and space in the prescribed manner (streams and cycles). It is customary to
distinguish three levels of agricultural technology - extensive, basic and intensive.

The innovation process determines competitive advantages and the growth of agricultural efficiency
in Russia, but its activity remains quite low (Table 1).

Table 1. Innovation in the agricultural sector of the Russian economy.

|                      | Share of Innovations in the Issue, % | The Share of Organizations Implementing, % |
|----------------------|--------------------------------------|-------------------------------------------|
| Plant growing        | 1.5                                  | 4.2                                       | 3.8                                       |
| Livestock            | 1.7                                  | 4.3                                       | 3.4                                       |
| Mixed farming        | 1.2                                  | 1.5                                       | 1.8                                       |
| Auxiliary operations | 1.3                                  | 2.1                                       | 1.7                                       |
| Total for the Russian economy | 7.8                          | 8.5                                       | 7.4                                       |

Out of the total number of progressive applied scientific and technical developments, less than 5% is
realized, and selection is carried out based on the results of an expert assessment of the current state and
prospects of technology change. These estimates are constructed as a chain of reasoning (rules) from
the knowledge base. The constant risk, the uncertainty of the market environment, the instability of
agricultural production conditions, the transition of the economy to the best available technologies
(BAT, «best available techniques») set the task of increasing the reliability of the assessment.

The prerequisites of this study were the ideas of other scientists:
- about the «materialization» of technology as its distinctive feature, which ensures the reduction of
  risks and costs of enterprises [3];
- on the continuous improvement of the structural components of industry technologies [4];
- about the possibility of maximizing the potential of the commercializability of the technology
  through analysis of the level of satisfaction of the properties of the components with the requirements
  imposed by investors, owners, consumers, regulatory authorities, etc.;
- on management selection as a process of systematization of structural components to be analyzed;
  determining the range of their permissible changes and their impact on the indicators of the operating
  cycle [5];
- on the development of an assessment methodology through the introduction of technology output
  indicators (productivity, cost, energy intensity) and a simplified modular structure of the technology,
  which avoids listing a large number of options for used machines, pesticides and fertilizers in order to
  reduce inefficient methods [6];
- on the possibility of reducing energy costs , achieving profitability of production not less than 25%,
  forming competitive advantages and providing leadership in the market with the introduction of
  advanced agricultural technologies [7];
- about adaptive resource-saving agricultural technologies based on the maximum use of the soil-
  climatic potential of the area and the assessment of their energy efficiency, as the ratio of the energy
  intensity of the grown crop to the total energy costs of the technology [8].

3. Study results

3.1. Structure-forming components of agricultural technology

The study of the accumulated volume of scientific and practical results of adaptive agricultural
technologies allowed us to identify eight structural components (Figure 1).
Briefly we describe these components:

1. **Input streams.** Through orientation and power, they mediate the temporal and spatial organization of technological operations, set the dynamics of the production process, determine energy consumption, material consumption, waste, safety and production efficiency. The material intensity of the technology determines its labor intensity and energy intensity, but sometimes less material-intensive products may have less useful effect (for example, they may be perishable or short-lived). This makes it necessary to evaluate the material-saving level of technology in each specific production by measuring the ratio of the mass of processed raw materials, the resulting product, the useful result and the negative external effect [9]. The use of combined units for soil treatment allows you to combine several operating flows in a single pass of equipment. Thus, the efficiency of dairy production is largely determined by the rational flow of harvesting, grinding, applying preservatives and distributing feed using a computerized multi-functional feed distributor. This organization of the cycle reduces the specific material consumption by 1.7 times and the specific energy consumption by 1.5-2 times [10].

2. **Output stream.** Specify the output parameters of the main technology (yield, cost, energy intensity) and the specific values of emissions, discharges and waste generation that are achievable in the associated environmental technology («commercial product + externalities»). At the initial stages of using new technologies, information on input and output streams can be unstable, contradictory, insufficiently verified, and conflicting, which increases the demand for fuzzy logic that gives the expert a greater degree of freedom [11].

3. **Volumetric-space parameters of objects.** Complex biological processes are conservative, they determine the multiverse of the industry technological cycle and the presence of the limit of the possible maximum productivity of animals and crop yields. Volumetric-space characteristics of the technology are recognized as an industry feature of the reproduction cycle in agriculture. The placement of fields, gardens, greenhouses, livestock complexes and other structures and communications depends on the prevailing technological order, which often does not allow developers-innovators to focus on
minimizing the size of the area, reducing the density of development and optimizing transport routes. The space determines the sequence of operations, equipping the production with equipment, devices, tools, dosing and control means, forms of labor organization. So, according to the required nutritional area, there are crops that require a small up to 0.005 m² (legumes and grains), an average 0.1-0.2 m² (corn, sunflower) and a large 1.0-2.5 m² land area. According to the degree of development of the root system, there are cultures with a highly developed deeper than 2.5 m (corn, sugar beets), moderately developed up to 1.5 m (potatoes, rye) and an underdeveloped 0.7-0.9 m system.

4. **Technological mode.** These are the best working conditions for organizing the processing of objects of labor and the transformation of raw materials flows - temperature, pressure, acidity, aggregate state of the medium, volumetric and linear flow rates, concentration of the working substance, quality and frequency of seed treatment, animal feeding rates, composition, doses of fertilizers, pesticides, biological products, types of solvents, fillers, duration of working strokes and other. In real conditions, it is impossible to single out one significant parameter; therefore, so it is necessary to normalize different types of costs, develop a single criterion for evaluating efficiency, and select the initial set of technological factors at each stage of the cycle.

5. **Materials, reagents, biological products.** The use of highly effective herbicides, fertilizers, meliorants, and biological products is not an alternative within the framework of basic and intensive agricultural technologies in large-scale production: Complete exclusion, replacement with organic products, or «strict» restriction is possible in the production of a limited amount of environmentally friendly products.

6. **Automation and computerization tools.** The digital economy is a strategic guideline for the development of the industry. Automated systems make agricultural technologies self-organizing, ultra-flexible and realize the synergistic potential of innovative development, reduce risks. «Smart greenhouses» and «smart firms» demonstrate high labor productivity and return on intellectual capital, increasing the quality and safety of production in General [12]. The availability of reference databases makes it easier to select experts.

7. **Machines, equipment, vehicles.** This is the most important multi-aspect and multi-level component of agricultural technology, forming its «core», often having a contradictory effect on production indicators and requiring a responsible approach from experts. Minimization of costs, capital productivity, cycle times, labor productivity, product quality are ensured by achieving the greatest conformity of the machine design to optimal conditions and production volumes in specific given circumstances. A few arguments:

   - increasing the volume of the grain harvester's hopper increases the utilization rate of the machine, but a filled hopper increases the energy consumption for transporting grain, and when the soil is wet, it dramatically increases the technogenic impact of the running system, destroying the structure, reducing the bunker's occupancy by 25-35% and soil fertility. But placing the hopper directly to the crawler frame truck leads to synergy effects - the reduced weight of the harvester, enhanced stability, improved permeability, increasing storage tank capacity, reduces the grinding of grain and technogenic load on the soil [13];

   - quality soil treatment depends on the design of the disks (flat, knife-shaped, wavy, spherical, spherical cut). The Great Plains company (USA) uses a spiral knife-shaped roller Turbo-chopper on soil processing units, the design of which differs in the angle of inclination of the knives along the radius of the roller, which improves the penetrating ability during the cutting of plant residues and prevents them from being pressed into the soil [14]. When processing high-stem crops, their splitting is achieved and the time of decomposition of plant residues in the soil is reduced, which prevents the spread of diseases and pests. The spiral shape of the rollers ensures constant contact with the soil, prevents its compaction, improves cutting action, reduces vibration and increases productivity [15]. However, for low-stem crops (up to 15 cm) or stony soil, these effects are not typical due to damage to the roller knife and clogging the space between the knives with plant residues and the soil;

   - «precision farming» technologies minimize negative environmental effects by tightening the requirements for design and performance indicators of equipment, taking into account the yield, energy
and labor costs, quality of work, and uniformity of the load on the machine. The benchmark are units for making organic fertilizer into the soil, competitive positions which are determined by the types of grinding, dosing and distributing of the working bodies (the angle of the helix, the speed of rotation of the drum, the angle of sharpening a knife, the feed rate of the mass of fertiliser, working width, etc.).

Another mandatory aspect of the examination is the reliability of the equipment and the stability of the process as a whole. Experts evaluate three types of equipment defects that can be eliminated: on the move (without stopping the equipment); when the equipment is stopped, but without immediate stopping, and those that require immediate stopping. Knowledge of production information about possible failures, breakdowns, failures in operation is the necessary competence of the expert, allowing him to calculate the probability of failure-free operation of the equipment, its «throughput», therefore, the volume of sales and the final financial result.

Thus, the optimal geometric shapes of the equipment are characterized by a rational design, minimal consumption of material and energy while maintaining operational properties. Their high cost will be offset by lower operating costs and resource savings. Modern software tools allow for the design of spherical, cylindrical or other shaped containers to develop structural and functional maps indicating the element structure of the product (weight, volume, material, etc.) and its various functions (main secondary, main, auxiliary, useless), which is in demand by experts.

8. The competence of the staff. Technological modernization increases intellectual capital, changes the requirements not only for personnel qualifications, but also for the design of the production environment, workplaces, and work clothes, and strengthens the role of organizational culture. The priority is the unique ability of the intellect to penetrate deeply into the fundamental scientific basis of processes and to understand the physical, chemical, biological, social, psychological, organizational, and managerial patterns of technological development.

The indicator determining the weight (importance) of these components is of fundamental importance. Depending on the type of agricultural technology, the actual soil and climate conditions of its application, and the resource capabilities of the organization, experts use various algorithms for establishing weight coefficients (pairwise comparison, ranking, Delphi method, etc.). On the example of a large poultry farm (Stavropol territory, 2017) that implements intensive broiler farming technology, the weight coefficients of the technology components are calculated using the cost method (Figure 1). The total weight at the level of 50% is the technological mode of poultry cultivation and biological products used in breeding, feeding, and veterinary services. The technology does not require large areas and special training of personnel, but involves a certain cycle of drying, processing and disposal of chicken manure.

3.2. The dynamics of costs

So, advanced agricultural technologies are aimed at minimizing resource consumption, maximizing the reduction of negative biosphere impact, maintaining the reproduction of the natural productivity of biological assets and land fertility. These goals are not always achievable in different economies and territories. Therefore, experts conduct a comprehensive assessment of the entire chain of technological operations, for example, in agriculture, from preparing the soil for sowing to storing grown products, and Supplement the functional approach with an analysis of costs and efficiency. The selection of the essential components of the technology, the determination of the range and limits of their permissible changes are necessarily carried out according to the efficiency criterion the boundary of which is considered the allowable operating costs per unit of output for a particular operation. The calculation is based on the determination of the proportion of the complexity of the operation in the total cost of labor prices and the minimum level of profitability.

Experts can use graphical methods to justify the decision. Let's assume that we compare three corn growing technologies that differ in soil and climate conditions, the type of equipment, the mode of soil treatment, the quality of fertilizers used, and, as a result, the level of variable and fixed costs. The yield versus cost curves help you identify the optimal application area for each technology, as a segment bounded by segments that correspond to the lowest costs (Figure 2).
The transition from one mode to another is determined by the goal setting, and technological operations serve as a tool for managing the process to achieve the planned yield and product quality while ensuring environmental safety and certain economic efficiency. For example, the cultivation of organic products due to the refusal from the use of chemicals and other methods of intensification of production, which reduces the productivity and directs technology 1, under certain market conditions, it is advisable to limit the yield on average 12 – 20 kg/ha, applying technology 3 technology, and in terms of intensification of production – technology 2.

3.3. The matrix map
The portfolio technology analysis uses a two-dimensional technology matrix map built in the coordinates «technology attractiveness – market position of an organization» that implements a significant number of technologies. When building it, the ordinate axis shows the importance of the technology (relative efficiency, productivity compared to the accepted standard), the abscissa axis shows the degree of use of the technology compared to competitors and its impact on costs. All technologies are distributed in four quadrants:
1 - the most important and attractive with a very low degree of use;
2 - the most important and attractive with a high degree of use, determining the market value of the organization;
3 - quite old, but important and unattractive technologies that occupy a strong and stable position in the market, do not require significant investment and are characterized by high commercial returns;
4 - technologies that have a weak commercial appeal and a weak position in the market, recommended for exclusion from the company’s portfolio.

For the tasks of expert assessment, the known distribution should be supplemented, the list of possible types of technologies expanded, and the dominant component specified (Figure 3). In the agricultural sector, there are simultaneously livestock production with outdated technological systems («museum» and «forced» technologies) and a plant growing company equipped with modern technology with space navigation («smart field»).
4. Conclusion
The presented structure of agricultural technologies is not exhaustive and comprehensive, it can be supplemented, and the components do not always clearly manifest and mutually penetrate each other. It illustrates the opinion of the outstanding thinker Manuel Castelis about technology as a method of using scientific knowledge to determine how to make things in a reproducible manner. It is the unconditional reproduction of components in each new modification of agricultural technology that allows them to be positioned as objects of comparison, which reflect the purpose and stability of the technological process, the adaptability of the technology to changing environmental conditions, resource provision, and safety. Understanding their essence makes it easier to build a generalized agreed point of view of experts about weighting factors; about factors that have a significant impact on the effectiveness of the technology.

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