

SUBSTANTIATION OF THE GENERAL MODEL OF AGROCLUSTERS AND THE COMPOSITION OF THE MACHINERY FLEET (USING RICE-GROWING CLUSTERS AS AN EXAMPLE)

Egamnazarov Bexzod Bahromjon o'g'li
Kimyo International University in Tashkent
Namangan Branch, Department of "Energy and Applied Sciences"
Associate Professor, PhD
b.egamnazarov@kiut.uz

Abstract:

This article presents the results of a study on the development of a general model of the rice cluster and the determination of the composition, types and quantity of the required machine park. The concept of "General model of a rice-growing cluster" is introduced and its definition is given. The general model for sown area is substantiated by the following sequence: regional rice clusters are grouped according to the values of sown area; clusters with the largest sown areas were selected from the groups and the corresponding variational series of numbers was formed; the upper limit of the mathematical expectation of this series is taken as the rational sowing area of the general model. Using the standard coefficients (numbers) of technical equipment required per 1 000 hectares of rice land, the composition, brands and number of tractors and agricultural machines that perform technological operations on the sowing area of the rice-growing cluster are determined. In rice growing clusters with a rational technical park, all agrotechnical operations are carried out at the optimum time and agricultural products adapted for processing are grown.

Keywords: Rice-growing tractor, general model, rational sown area, technological operation, rice cultivation, fleet of machines, composition, type, quantity, effect.

Introduction

In the agriculture of Uzbekistan, the cluster system, which is a completely modern form of management based on market mechanisms, has fully justified itself in practice. At present, clusters account for 100% of the cotton and grain and more than 40% of the fruits and vegetables produced in the country. Clusters are carrying out such important tasks as modernizing agriculture, industrializing the sector, deep processing of products, and ultimately exporting finished products rather than raw materials. As a result, in cotton growing alone, the fiber-processing rate has increased 2.5 times. Owing to the processing of 100% of the harvest, yarn production has doubled and the volume of finished products

has tripled [1].

Specialized clusters have been established in our country to ensure high-yield rice production and to organize the industrial processing of paddy into rice and rice products. Their number is increasing from year to year. This is not accidental, because rice, which is one of the main ingredients of Uzbek cuisine, is obtained from the rice plant. Therefore, the demand for rice remains consistently high.

To fully meet this demand, it is necessary to create new intensive and water-saving rice-growing technologies, improve existing ones, develop efficient technical means for their implementation, and provide rice-growing clusters and farms with such machinery.

To achieve high production indicators, each rice-growing cluster should have a machinery fleet capable of ensuring that all technological operations, from plowing and sowing to harvesting and transportation, are performed within the optimal time limits specified in the “Model Technological Cards for the Care of Agricultural Crops and Production” [2]. Failure to fully equip clusters with the required set of machines adversely affects not only the timing of field operations but also crop yields and the quality of raw materials.

The absence of regional (by province) and general (republic-wide) models of rice-growing clusters based on land area further increases the strength of this negative effect. Accordingly, there is a need to develop a model of a rice-growing cluster and a computational methodology for substantiating the composition, models, and number of machines that should be on its balance sheet [3].

The objective of the research is to increase the level of mechanization in rice cultivation by developing a general model of a rice-growing cluster and substantiating the composition, models, and number of technical means that should be on its balance sheet.

Materials and Methods

The objective of the research is to increase the level of mechanization in rice cultivation by developing a general model of a rice-growing cluster and substantiating the composition, models, and number of technical means that should be maintained on its balance sheet. The research object comprised the rice-growing clusters operating in the Republic of Uzbekistan and the crop areas assigned to them. Official data obtained from the Ministry of Agriculture of the Republic of Uzbekistan were used as the primary information base. The study employed monographic observation, synthesis and analysis of information, comparative analysis, and the principles and methods of “Formation of Machine-Tractor Units” and “Mathematical Statistics.”

At the first stage, the rice-growing clusters were systematized by region and arranged in ascending order according to the size of their assigned rice-growing areas. Clusters with relatively close land-area values were combined into groups using the grouping-step approach, where the grouping step was defined as the difference between the land areas of adjacent clusters. For each resulting group, the largest land area was accepted as the rational land area of that group, while observations that differed sharply from the group values were considered separately.

At the second stage, the rational land-area values obtained for the regional groups were combined into a variation series. Because the number of observations was $N = 8$, i.e., less than 30, small-sample statistical procedures were applied. The arithmetic mean, adjusted variance, standard deviation, coefficient of variation, and the lower and upper confidence limits of the mathematical expectation were calculated. A confidence probability of 0.95 was adopted, and the corresponding Student's *t*-distribution coefficient was used. The upper confidence limit of the mathematical expectation was accepted as the rational rice-growing area of the general cluster model.

At the final stage, the required machinery fleet was determined for the rational model area. The

calculations used the existing normative coefficients (Mt) specifying the number of each type of tractor and agricultural machine required per 1,000 hectares. For each type of technical means, the required quantity (Tt) was calculated in proportion to the rational area of the model cluster using $Tt = (Esh \times Mt) / 1000$, with the resulting values rounded to practical whole-unit quantities. This procedure provided the basis for determining the composition, models, and total number of machines required to perform the full set of rice cultivation operations within the established agrotechnical periods.

Results

Based on data obtained from the Ministry of Agriculture of the Republic of Uzbekistan, the number of rice-growing clusters operating in the regions and the land areas assigned to them are presented in Table 1.

Table 1. Information on the Number and Land Areas of Rice-Growing Clusters Operating in the Regions of the Republic

№	Name of region	Clusters	
		number	land area, ha
1	Republic of Karakalpakstan	7	6027
2	Andijan	12	2335
3	Namangan	1	2935
4	Surkhandarya	1	366
5	Syrdarya	2	9494
6	Tashkent	10	6226
7	Fergana	3	3418
8	Khorezm	5	10040
Total:		41	40 841

As can be seen from the table, rice-growing clusters have not yet been established in Bukhara, Jizzakh, Kashkadarya, and Navoi regions.

We determine the rational values of the land areas of rice-growing clusters by region in the following order.

For the Republic of Karakalpakstan (Table 2).

First, based on the table data obtained from the Ministry of Agriculture, we arrange the clusters in ascending order of the rice areas assigned to them (Table 2). We divide the clusters in Table 2 into groups using the method given in source [4]. Here, Sh_i is the rice area of the clusters and Sh_g is the grouping step.

Table 2. Groups of Rice-Growing Clusters in the Republic of Karakalpakstan by Land Area

№	Cluster name	Sh_i , ha	Sh_g , ha
1	“Rice-Growing Cluster” LLC	150	Sh_1
2	“Xusaynov Javlonbek” farm	177	Sh_2
3	“Ubaydullayev Batirbay” farm	250	Sh_3
4	“AGRO ECO COMPLEX” LLC	250	Sh_4
5	“SHOMANAY SHALI KLAster” LLC	350	$Sh_{g1}=350$
6	“KUNGRAD RICE CLUSTER” LLC	1000	Sh_6
7	“Juzbasi” farm	3850	Sh_7

We call clusters 2, 3, 4, and 5 the first group of clusters. We introduce the concept of a grouping step

and denote this step by the symbol ΔMg . The grouping step is the difference between the rice areas of two adjacent clusters. For Group 1, $\Delta Mg_1 = 350 - 250 = 100$ ha. As can be seen from the table, $177 - 150 = 27 < \Delta Mg_1 = 100$ ha; $1000 - 350 = 650 > \Delta Mg_1$, and $3850 - 1000 = 2850 > \Delta Mg_1 = 100$ ha. We accept the largest rice area in the group, $Sh_5 = 350$ ha, as the rational area of the group, $Sh_{g1} = 350$ ha.

We do not include clusters 1, 6, and 7 in the group because their areas differ sharply from $Sh_{g1} = 350$ ha and their steps differ sharply from $\Delta Mg_1 = 100$ ha. We denote these areas by the symbols Sh_1 , Sh_6 , and Sh_7 [5].

For Andijan Region (Table 3).

Table 3. Groups of Rice-Growing Clusters in Andijan Region by Land Area

№	Cluster name	Sh_i, ha	Sh_g, ha
1	“Yuldashev Oybek yerlari” LLC	50	Sh ₁
2	“Boymatov Muftoxiddin” farm	54	Sh ₂
3	“Saminjon Shamsiyev” farm	90	Sh ₃
4	“Agronomiy RISK” farm	92	Sh _{g1}
5	“Akromjon Ixtiyor” farm	165	Sh ₅
6	“Paxtaobod Agrotaminot” LLC	189	Sh ₆
7	“Oltin vodiya saxovat” LLC	205	Sh ₇
8	“Baraka Agroklastar” LLC	219	Sh ₈
9	“Zayxurmaks” LLC	256	Sh ₉
10	“Agrokafolat” LLC	302	Sh ₁₀
11	“Agroinnovatsiya klaster” LLC	334	Sh ₁₁
12	“Abduxoshim yer bo‘stoni” farm	379	Sh _{g2}

We combine clusters 1-4 into Group I and take its rational land area as $Sh_{g1} = 92$ ha. We include the remaining clusters in Group II and accept $Sh_{g2} = 379$ ha.

We cannot combine the clusters in Namangan, Surkhandarya, and Syrdarya regions into groups because the number of clusters is too small: 1, 1, 2 < 3.

For Tashkent Region (Table 4).

Clusters 2, 3, 4, 5, and 6 form Group I, with $Sh_{g1} = 492$ ha. Clusters 7, 8, and 9 form Group II, with $Sh_{g2} = 918$ ha. Because the land areas of clusters 1 and 10 (50 and 2700 ha) are much smaller and larger than the others, respectively, we do not include them in the groups and denote them as Sh_1 and Sh_{10} .

Table 4. Groups of Rice-Growing Clusters in Tashkent Region by Land Area

№	Cluster name	Sh_i, ha	Sh_g, ha
1	2	3	4
1	“Sherzodbek” LLC	50	Sh ₁
2	“Eko Food Rich” LLC	223	Sh ₂
3	“BEKOBOD – RICE” LLC	300	Sh ₃
4	“Gold Granate” LLC	321	Sh ₄
5	“EASTERN PREMIUM RICE” LLC	452	Sh ₅
6	“Sholi Agro Invest” LLC	492	Sh _{g1}
7	“Yangiyol Rice Supply” LLC	724	Sh ₇
8	“BEKOBOD – GOLD – RICE” LLC	770	Sh ₈

9	“REAL AGROTEX” LLC	918	Sh _{g2}
10	“TCT RICE” LLC	2700	Sh ₁₀

For Fergana Region (Table 5)

Table 5. Groups of Rice-Growing Clusters in Fergana Region by Land Area

№	Cluster name	Sh _i , ha	Sh _g , ha
1	“Soliyev Abdujalil” farm	265	Sh ₁
2	“YOZYVON PROVIDER RICE Expo CLUSTER” LLC	1360	
3	“Yangiqadam oq oltin xirmoni” farm	1793	Sh _{g1}

For Fergana Region, clusters 2 and 3 form Group I: Sh_{g1} = 1793 ha. Sh₁ = 265 ha remains separate.

For Khorezm Region (Table 6).

Table 6. Groups of Rice-Growing Clusters in Khorezm Region by Land Area

№	Cluster name	Sh _i , ha	Sh _g , ha
1	“Dostonbek” farm	1355	
2	“Shoxjaxon Shoxruxxon Paxlavonlari” farm	1355	Sh _{g1}
3	“Sanjar Grand” LLC	2300	
4	“Erkin Rais Ota Rice-Growing Cluster” LLC	2300	
5	“Khorezm Nurli Zamin” farm	2730	Sh _{g2}

For Khorezm Region, we include clusters 1 and 2 in Group I, and clusters 3, 4, and 5 in Group II. The rational land areas of the groups are Sh_{g1} = 1355 ha and Sh_{g2} = 2730 ha.

To develop the general model of rice-growing clusters, we combine the groups of rational clusters from Tables 2-6 in one place: Sh_{g1} = 350 ha; Sh_{g1} = 92 ha; Sh_{g2} = 379 ha; Sh_{g1} = 492 ha; Sh_{g2} = 918 ha; Sh_{g1} = 1793 ha; Sh_{g1} = 1355 ha; Sh_{g1} = 2730 ha.

These figures form the following set of numbers (unit of measurement: hectares):

Sh_i: 350; 92; 379; 492; 918; 1793; 1355; 2730. (1)

The total number of values in the set of numbers in (1) is the number of variants, N = 8. Therefore, this set is a variation series consisting of N = 8 numerical variants. Since N = 8 < 30, the mathematical expectation of the Sh_i values, the variance d, the standard deviation, the coefficient of variation, and the lower Sh_p and upper Sh_{yu} limits of the mathematical expectation are calculated using the following formulas [5]: $\bar{Sh}\sigma_{sh}\vartheta_{sh}$

mathematical expectation -

$$\bar{Sh} = \frac{\sum_{i=1}^N Sh_i}{N} \quad \text{or} \quad \bar{Sh} = \frac{\sum_{i=1}^8 Sh_i}{8}; \quad (2)$$

adjusted variance -

$$d = \frac{1}{N-1} \sum_{i=1}^N (Sh_i - \bar{Sh})^2 \quad \text{or} \quad d = \frac{1}{7} \sum_{i=1}^7 (Sh_i - \bar{Sh})^2; \quad (3)$$

standard deviation -

$$\sigma_{sh} = \sqrt{d}; \quad (4)$$

coefficient of variation -

$$\vartheta_{sh} = \frac{\sigma_{sh}}{\bar{Sh}} \cdot 100\%. \quad (5)$$

The lower Sh_p and upper Sh_{yu} boundary values of the confidence interval of the mathematical expectation are: $\bar{Sh}$

$$Sh_p = \bar{Sh} - t_{\alpha} \frac{\sigma_{sh}}{\sqrt{N}}, \quad Sh_{yu} = \bar{Sh} + t_{\alpha} \frac{\sigma_{sh}}{\sqrt{N}}. \quad (6)$$

In expression (6), the coefficient is the Student's t-distribution coefficient, determined from Table 8 of source [6] according to the degree of freedom r = N - 1 and the adopted confidence probability level (α). Since N = 8, r = 8 - 1 = 7. We accept α = 0.95. For r = 7 and α = 0.95, Table 8 gives t_α = t_{0.95} =

2.45. Substituting $N = 7$ and $t_{0.95} = 2.45$ into expression (6), we obtain: t_{α}

$$Sh_p = \bar{Sh} - 2.45 \frac{\sigma_{sh}}{\sqrt{7}} \quad \text{or}$$

$$Sh_p = \bar{Sh} - 0.926 \sigma_{sh}; \quad (7)$$

$$Sh_{yu} = \bar{Sh} + 0.926 \sigma_{sh}. \quad (8)$$

Substituting the numbers in set (1) into expression (2), we find the value of the mathematical expectation:

$$\bar{Sh} = \frac{1}{8} (350 + 92 + 379 + 492 + 918 + 1793 + 1355 + 2730) = \frac{1}{8} * 8109 = 1013 \text{ ha.}$$

(3) Using expression (3), we calculate the value of the adjusted variance:

$$\begin{aligned} d &= \frac{1}{7} [(350 - 1013)^2 + (92 - 1013)^2 + (379 - 1013)^2 + (492 - 1013)^2 + (918 - 1013)^2 + \\ & (1793 - 1013)^2 + (1355 - 1013)^2 + (2730 - 1013)^2] = \frac{1}{7} [(-663)^2 + (-921)^2 + (-634)^2 + \\ & (-521)^2 + (-95)^2 + 780^2 + 342^2 + 1717^2] = \frac{1}{7} (439569 + 848241 + 401956 + 271441 + \\ & 9025 + 608400 + 116964 + 2948089) = \frac{1}{7} * 5643685 = 806241 (ha)^2. \end{aligned}$$

Based on expression (4), we determine the standard deviation:

$$\sigma_{sh} = \sqrt{806241} = 898 \text{ ha.}$$

The value of the coefficient of variation according to expression (5) is:

$$V_{sh} = \frac{898}{1013} * 100\% = 88 \%.$$

According to expressions (7) and (8), we calculate the lower and upper boundary values of the mathematical expectation: Sh_p, Sh_{yu}

$$Sh_p = 1013 - 0.926 * 898 = 1013 - 831 = 182 \text{ ha};$$

$$Sh_{yu} = 1013 + 0.926 * 898 = 1013 + 831 = 1844 \text{ ha.}$$

We propose taking the rational rice area E_{sh} of the general model of the rice-growing cluster, with 95% confidence, as equal to the upper limit of the mathematical expectation, i.e., $E_{sh} = Sh_{yu} = 1844 \text{ ha.}$

Discussion

The general model of a rice-growing cluster can be called an empirical model because it was constructed through statistical analysis of data on the territorial distribution, number, and sizes of the assigned land areas of the rice-growing clusters operating in the republic, i.e., the research object [7]. In farms specializing in rice production in our republic, seeds are sown on dry fields using seed drills or broadcast onto flooded fields. In advanced clusters and farms, rice seedlings are transplanted by special machines onto areas vacated after grain harvesting [8].

It is known that seeds are broadcast manually onto flooded fields. In this case, it is impossible to distribute the seeds evenly over the field surface. This method is very labor-intensive and costly because it is performed by manual labor; most importantly, the worker must constantly move through water [9].

Planting rice by the seedling method using machines is a progressive method. However, it depends on the water supply of the region. This method can be used only if sufficient water is available when the fields are vacated after grain harvesting. Taking the above into account, for the model rice-growing cluster we propose using the method widely applied in practice - sowing seeds on dry fields with seed drills - and calculating the types and numbers of the required technical means on this basis [10].

For the rational land area $E_{sh} = 1844 \text{ ha}$ of the model farm, we calculate the composition and number

of technical means required for sowing rice seeds on dry fields with seed drills according to the procedure described in source [11]. In the calculations, we use the standards (Mt) for the technical means required per 1,000 hectares of field area presented in Chapter XII of that source. We enter the calculation results in Table 7. Column 2 of the table presents the names, types, and models of the selected technical means; Column 3 gives the standard number (Mt) of such machinery required per 1,000 hectares; and Column 4 gives the number required for Esh = 1844 hectares (Tt) [12].

For crawler plowing tractors. Plowing rice fields using plowing units based on crawler tractors gives good results because such tractors can move without slipping even on land with relatively high moisture content. The required number of crawler tractors is:

$Tt = (Esh \cdot Mt)/1000 = 1844 \cdot 8.572/1000 = 15.8 \approx 16$ units (entered in Row 1 of Table 7).

Transport tractors (Row 2 of Table 7): $Tt = (1844 \cdot 12)/1000 = 22.1 \approx 21$ units [13].

Deep soil-loosening machines (Row 3 of Table 7): $Tt = (\text{units. } \frac{1844}{3} \cdot 2,857)/1000 = 1,7 \approx 2$

Laser land levelers (Row 4 of Table 7): $Tt = (\text{units. } \frac{1844}{3} \cdot 4)/1000 = 2,46 \approx 3$

Mineral fertilizer spreaders (Row 5 of Table 7):

$Tt = (1844 \cdot 3.846)/1000 = 7.09 \approx 7$ units.

Organic fertilizer spreaders (Row 6 of Table 7): $[(1844 \cdot 0.2) \cdot 10]/1000 = 3.68 \approx 4$ units.

Tractor trailers (Row 7 of Table 7): according to the standard, one trailer is selected for each transport tractor. Therefore, 21 trailers are required.

Required number of plows (Row 8 of Table 7): the standard for plows is accepted as one plow per plowing tractor. Therefore, 16 plows are required for 16 crawler tractors.

Seedbed preparation machines (Row 9 of Table 7): $Tt = (1844 \cdot 5.714)/1000 = 10.5 \approx 10$ units.

Set of tooth harrows (Row 10 of Table 7): $Tt = (1844 \cdot 2)/1000 = 3.68 \approx 4$ units.

Rice-field bund forming machines (Row 11 of Table 7): $Tt = (1844 \cdot 2.164)/1000 = 3.99 \approx 4$ units.

Rice seed drills (Row 12 of Table 7): $Tt = (1844 \cdot 4.219)/1000 = 7.77 \approx 8$ units.

Rice-field pesticide sprayers (Row 13 of Table 7): $Tt = (1844 \cdot 32)/1000 = 59$ units.

Rice combine harvesters (Row 14 of Table 7): $Tt = (1844 \cdot 11.11)/1000 = 20.48 \approx 20$ units.

Rice straw and stubble collection machines (Row 15 of Table 7): $Tt = (1844 \cdot 2.02)/1000 = 3.72 \approx 4$ units [14].

Table 7. Information on the Composition and Calculated Number of Technical Means Required for the Model Rice-Growing Cluster

DATA

No.	Name, type, and model of machinery	Required per 1,000 hectares, Mt, units	Required for Esh = 1844 hectares, Tt, units
1	Wheeled plowing tractors: ARION-630C; MX-135; TS-135; NEW HOLLAND T7060 type	5.714	15
2	Crawler plowing tractors: BT-150D; XTZ-181; Belarus-2103; T-4A-01; BT-100D; T-402.01 type	8.572	16
3	Transport tractors: TTZ-100KR; MTZ-82R type	12	21
4	Deep soil-loosening machines: GRX-2-50; GRP-3/5; GNU-1MS; GR 270/370 type	2.857	2
5	Laser land levelers: PL-3; PL-3.5; PL-5 type	4	3
6	Mineral fertilizer spreaders: RMU-0.5M; 1-RMG-4B type	3.846	7
7	Organic fertilizer spreaders: RTP-5-OU.SK1; ROU-6 type	10	4
8	Tractor trailers: AT-4; 2PTS-4-793A-04A; 2PTS-4-887; 2PTS-4-793A-01 type	1 unit per transport tractor	21

9	Plows for crawler tractors BT-150D; XTZ-181; Belarus-2103; T-4A-01; BT-100D; T-402.01: PYA-3-35-2; MR-4A-2/3-45; PLN-4-35 type	8.572	16
10	Seedbed preparation machines: combined machines of the “ZIRKON 7/250” and “RUBIN 9/250” types	5.714	10
11	Tooth harrows: BZSS-1.0; BZTS-1.0 or BZTX-1.0 type	2 sets	4
12	Rice-field bund-forming machines: KZU-0.3D type	2.164	4
13	Rice seed drills: “AMAZONE”, M02.04 type	4.219	8
14	Rice-field pesticide sprayers: OG-101 “AIDA” hand-held units	32	59
15	Rice combine harvesters: “YENISEY 1200 NM”, “DOMINATOR-204”, “MEGA”, 4LZ-2.0D type	11.11	20
16	Rice straw and stubble collection machines: “Markant-55”, “Massey Ferguson” MF 1839 XC pickup baler	2.02	4

Thus, in a model rice-growing cluster with a rational land area of 1844 hectares, 214 tractors and agricultural machines of 16 types are required for sowing seeds on dry fields, caring for the plants, and harvesting the mature crop [15].

Conclusions

Developing a general model of a rice-growing cluster is an important scientific and methodological issue. The proposed definition also confirms this. The general model of rice-growing clusters is a theoretical cluster in which such parameters as the area receiving mechanized services, the composition and quantity of technical means, and the structure and capacity of the repair and maintenance base of the groups of clusters with the largest land areas in the Republic of Karakalpakstan and the regions are reflected relatively fully.

A variation-statistical method for determining the rational land area of the general model was developed, including the following stages:

rice-growing clusters operating in the regions of the republic were divided into groups according to the size of the land areas assigned to them; those with the largest land areas were selected from within the groups and a specific set of numbers was formed; the mathematical expectation, standard deviation, and lower and upper limits of the mathematical expectation of the variation series were calculated; the upper limit Shyu of the mathematical expectation was accepted as the rational land area of the general model of the rice-growing cluster:

$E_{sh} = Sh_{yu} = 1844 \text{ ha.}$

Using the existing standard (Mt) coefficients for the number of tractors and agricultural machines required per 1,000 hectares of crop area, the types (16) and total number (214 units) of technical means that ensure full mechanization of rice-growing operations on the rational land area (E_{sh}) of the general model were determined.

In rice-growing clusters with a rational machine-tractor fleet in terms of the types and number of technical means, all agrotechnical operations are performed within optimal time limits and agricultural products suitable for processing are produced.

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