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VALUE CHAIN ANALYSIS OF SWEET SORGHUM IN FARMS OF THE REPUBLIC OF KARAKALPAKSTAN: RESULTS OF A FIELD SURVEY

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Abstract. *This paper presents the results of a field survey of 72 farms across nine districts of the Republic of Karakalpakstan that cultivate sweet sorghum (Sorghum bicolor (L.) Moench). The aim is to assess the structure of the crop's value chain and to identify the key constraints to its development. Descriptive statistics, analysis of variance and correlation analysis were applied. The mean yield was 4.0 t/ha and differed significantly among districts (Analysis of variance: $F = 19.55$; $p < 0.001$). The value chain is markedly raw-material-oriented: 78% of farms sell the product unprocessed, processing and cooperation are absent (0%), and 96% of farms are price takers at the prevailing market price. Access to credit and subsidies does not exceed 1.4%. The principal constraints identified are irrigation-water shortage (92%), lack of financial resources (85%) and outdated machinery and technology (58%). The study concludes that the development of processing, cooperation and water-saving technologies is required.*

Keywords: *sweet sorghum, value chain, farms, Republic of Karakalpakstan, yield, agricultural economics, Aral Sea region, development constraints.*

Annotatsiya. *Mazkur maqolada Qoraqalpog'iston Respublikasining to'qqiz tumanida qand jo'xori (Sorghum bicolor (L.) Moench) yetishtiruvchi 72 ta fermer xo'jaligida o'tkazilgan dala so'rovi natijalari keltirilgan. Tadqiqotning maqsadi ushbu ekinning qiymat zanjiri tuzilmasini baholash hamda uning rivojlanishiga to'sqinlik qilayotgan asosiy omillarni aniqlashdan iborat. Tadqiqotda tavsifiy statistika, dispersion tahlil (ANOVA) va korrelyatsion tahlil usullaridan foydalanildi. O'rtacha hosildorlik 4,0 t/ga ni tashkil etdi va tumanlar kesimida statistik jihatdan ishonchli farq qilishi aniqlandi (dispersion tahlil: $F = 19,55$; $p < 0,001$). Natijalar qiymat zanjiri asosan xomashyo yo'nalishiga ega ekanligini ko'rsatdi: fermer xo'jaliklarining 78 foizi mahsulotni qayta ishlamasdan sotadi, qayta ishlash va kooperatsiya amalda mavjud emas (0%), xo'jaliklarning 96 foizi esa bozorda shakllangan narx bo'yicha mahsulot sotuvchi narx qabul qiluvchilar hisoblanadi. Kredit va davlat subsidiyalaridan foydalanish darajasi 1,4 foizdan oshmaydi. Tadqiqot davomida asosiy cheklovchi omillar sifatida sug'orish suvi tanqisligi (92%), moliyaviy resurslarning yetishmasligi (85%) hamda eskirgan texnika va texnologiyalardan foydalanish (58%) aniqlandi. Tadqiqot natijalari qayta ishlash sanoatini rivojlantirish, qishloq xo'jaligi kooperatsiyasini kengaytirish va suvni tejovchi texnologiyalarni joriy etish zarurligini ko'rsatadi.*

Kalit so'zlar: *qand jo'xori, qiymat zanjiri, fermer xo'jaliklari, Qoraqalpog'iston Respublikasi, hosildorlik, qishloq xo'jaligi iqtisodiyoti, Orolbo'yi mintaqasi, rivojlanish cheklovlari.*

Аннотация. *В данной статье представлены результаты полевого обследования 72 фермерских хозяйств, выращивающих сахарное сорго (Sorghum bicolor (L.) Moench), в девяти районах Республики Каракалпакстан. Цель исследования заключается в оценке структуры цепочки создания стоимости данной культуры и выявлении основных факторов, сдерживающих ее развитие. В исследовании применены методы описательной статистики, дисперсионного анализа и корреляционного анализа. Средняя урожайность составила 4,0 т/га и статистически значимо различалась между районами (дисперсионный анализ: $F = 19,55$; $p < 0,001$). Установлено, что цепочка создания стоимости имеет ярко выраженную сырьевую направленность: 78% фермерских хозяйств реализуют продукцию без переработки, переработка и кооперация отсутствуют (0%), а 96% хозяйств являются ценополучателями, реализующими продукцию по сложившейся рыночной цене. Доступ к кредитам и государственным субсидиям имеют не более 1,4% хозяйств. Ключевыми ограничивающими факторами являются дефицит оросительной воды (92%), недостаток финансовых ресурсов (85%) и использование устаревшей техники и технологий (58%). По результатам исследования сделан вывод о необходимости развития переработки, сельскохозяйственной кооперации и внедрения водосберегающих технологий.*

Ключевые слова: *сахарное сорго, цепочка создания стоимости, фермерские хозяйства, Республика Каракалпакстан, урожайность, экономика сельского хозяйства, регион Аральского моря, факторы развития.*

INTRODUCTION

Sweet sorghum (Sorghum bicolor (L.) Moench) tolerates both drought and soil salinity well, which makes it well suited for arid and saline lands. It has attracted particular attention to biomass production in saline areas due to its combination of drought tolerance and salinity (Calone et al., 2020), and can serve as an alternative summer crop for biofuel production in conditions of limited irrigation water (Vasilakoglou et al., 2011). Its stems accumulate sugar in high concentrations — the sugar content in Brix juice usually ranges from 16 to 23% (Basavaraj et al., 2013) — and the plant produces a large amount of biomass. Together, these properties make it a useful raw material for the production of several products: the juice can be processed into granulated sugar, syrups and jaggery or fermented to produce ethanol, and the cake left after juicing serves as animal feed and raw materials for the production of cellulosic ethanol, paper, pellets from biomass and electricity generation (Appiah-Nkansah et al., 2019). Since corn requires fewer nitrogen fertilizers and uses water more efficiently than corn, and loses less than a quarter of its biomass when grown on saline rather than unsalted lands, it is considered a promising low-cost raw material for marginal soils (Wang et al., 2022). The drying up of the Aral Sea led to an increase in soil and water salinity and a sharp reduction in freshwater reserves available for irrigation (Micklin, 2007); according to UN estimates, by 2001 46% of irrigated lands in Uzbekistan had suffered from salinization, compared with 38% in 1982, which led to a slight decrease in yields by as much as two a third. Later field studies confirm that the problem persists:

water salinity, measured as the total amount of dissolved solids in Karakalpakstan, ranged from 563 to 3852 mg/l (Bartrem et al., 2025). Against this background, there is a shortage of salt water, degraded soils, and drought— and salt—tolerant crops are a practical way to diversify agriculture and increase rural incomes.

However, none of these potentials can be realized without an active value chain — from the supply of raw materials and production to post-harvest processing, processing and marketing. In agriculture, the value chain encompasses all value-adding activities, from the supply of raw materials, production, and processing through storage, transportation, wholesale, and retail to final consumption, and value chain analysis is used to identify constraints and opportunities to modernize and enhance the competitiveness of small farmers (Kaplinsky & Morris, 2001). In Central Asia, these chains remain poorly developed and insufficiently studied (Rillo & Nugroho, 2016), and in Karakalpakstan, in particular, little attention has been paid to these links. In our study, this gap was eliminated using data from a detailed farm survey. We decided to describe the structure of the value chain of sugar sorghum in the region based on primary data, assess how productive and profitable the surveyed farms actually are, and identify the factors that currently hinder the development of the industry (**Djanibekov, N**).

MATERIALS AND METHODS

The data source. The empirical basis was a questionnaire survey of farms conducted in 2025-2026 using the structured tool “So‘rovnoma qand jo‘xori”. The tool included 181 indicators grouped by thematic blocks: socio-demographic characteristics, land use, agronomy, irrigation, supply and marketing, post-harvest losses, institutional support, labor resources, climate impact and ranking of problems. Sample. In total, 72 completed questionnaires were received in 9 districts of the Republic of Karakalpakstan and the main analytical database was compiled. The distribution of farms by region is shown in Figure 1.

Analytical methods. Descriptive statistics (mean, median, standard deviation, and range) were calculated for the main variables. One-factor analysis of variance (ANOVA) was used to compare yields in different areas, and Pearson correlation analysis was used to identify the relationship between yields and farm characteristics. Given the modest sample size and the uneven number of farms in each district, the comparison between districts was further verified using the nonparametric Kruskal-Wallis test, which assumes no normality or equal deviations (Kruskal & Wallis, 1952; the results are presented together with ANOVA. The differences were considered statistically significant at $p < 0.05$. All calculations were performed in Python using the pandas and SciPy libraries.

Data processing. In accordance with the principle of preserving primary data, all responses were entered verbatim, and no values were changed during data entry. Two yield indicators (24 and 40 t/ha) were processed separately at the analysis stage. Both exceed the acceptable range for sorghum sugar yields by a wide margin (the grain yield of this crop is usually well below 2 t/ha), but it is within the range typical for accounting for fresh green mass (whole plant biomass), which usually reaches several tens of tons t/ha (Echevarria Laza et al., 2020). Therefore, we interpreted these two figures as a discrepancy in units of measurement, rather than as the actual grain/stem yield, and excluded them from yield calculations. To confirm that this decision did not affect the results, we recalculated the descriptive statistics and the comparison between the districts while maintaining the two values; the focus and significance of the results did not change, and these two figures only affected the value of the overall average. Thus, the presented performance estimates are based on a cleaned data set, and complete (uncleaned) data is provided upon request.

RESULTS AND DISCUSSION

Survey geography. The survey covered nine districts of the republic. The largest numbers of farms are in Beruniy (18; 25.0%), Chimbay (16; 22.2%) and Nukus (14; 19.4%) districts; 7 farms each were surveyed in Takhtakupir and Kanlykul districts, 4 in Takhiatash, and 2 each in Bozatau, Karauzyak and Kegeyli. The spatial distribution of the sample and the mean yield by district are presented in Figure 1.

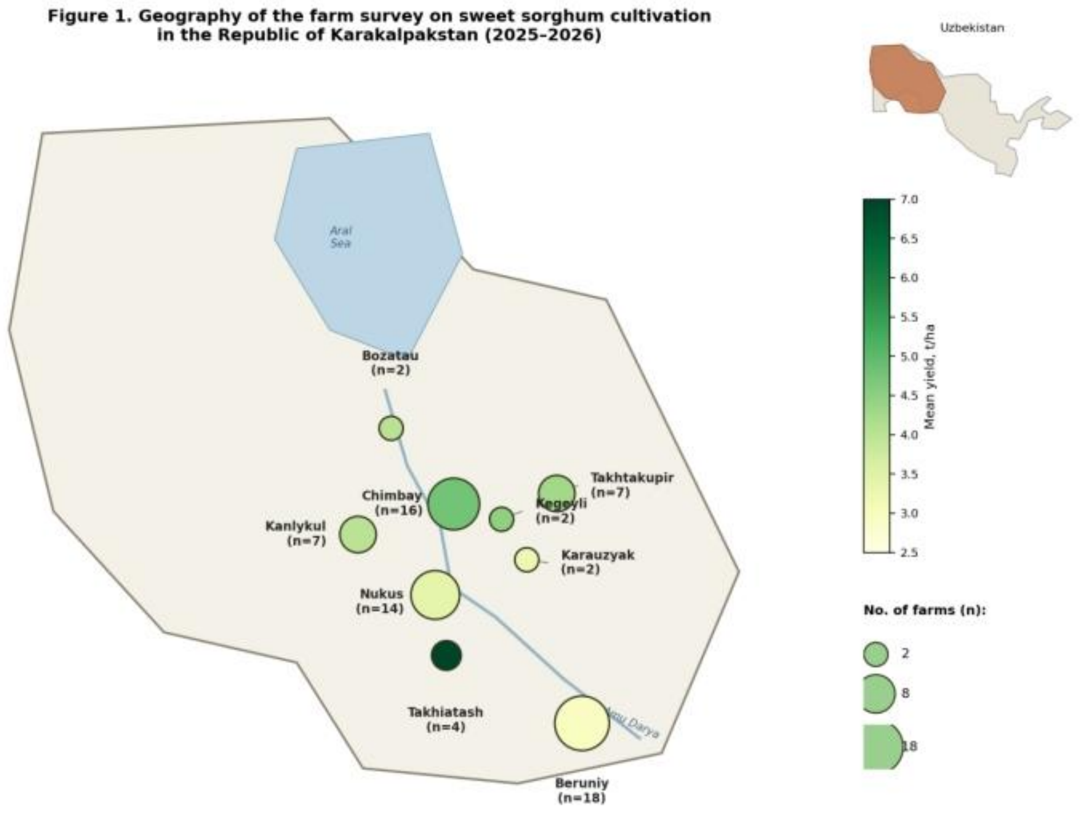

Figure 1 — Survey geography and mean sweet sorghum yield by district, Republic of Karakalpakstan

Farm characteristics. The socio-demographic profile of respondents is typical of the region: 84.7% are men, the mean age is 45 years and the mean farming experience is 18 years. A high level of education (bachelor's degree and above) was recorded for 76.4% of respondents. Land is leased by 31.9% of farms; 38.9% have an off-farm income source. The mean area under sweet sorghum is 7.4 ha (Table 1); in all farms the sorghum area coincides with the total cropped area, indicating their narrow specialization.

Table 1 — Socio-economic characteristics of the surveyed farms

Indicator	n	Mean	Median	Range (min–max)
Farmer age, years	65	45.1	44	30–63
Farming experience, years	72	18.3	15	5–50
Years of education	49	15.0	16	10–20
Household size, persons	41	5.3	6	2–8
Sweet sorghum area, ha	72	7.4	7.0	2–20

Productivity and its determinants. The mean sweet sorghum yield was 4.0 t/ha (median 4.0; range 2–7 t/ha). The analysis of variance revealed statistically significant inter-district differences ($F = 19.55$; $p < 0.001$). The highest values were recorded in Takhiatash (7.0 t/ha) and Chimbay (4.8 t/ha) districts, the lowest in Beruniy (2.9 t/ha) and Karauzyak (3.2 t/ha), reflecting differences in soil-reclamation conditions and irrigation-water availability (Figure 2).

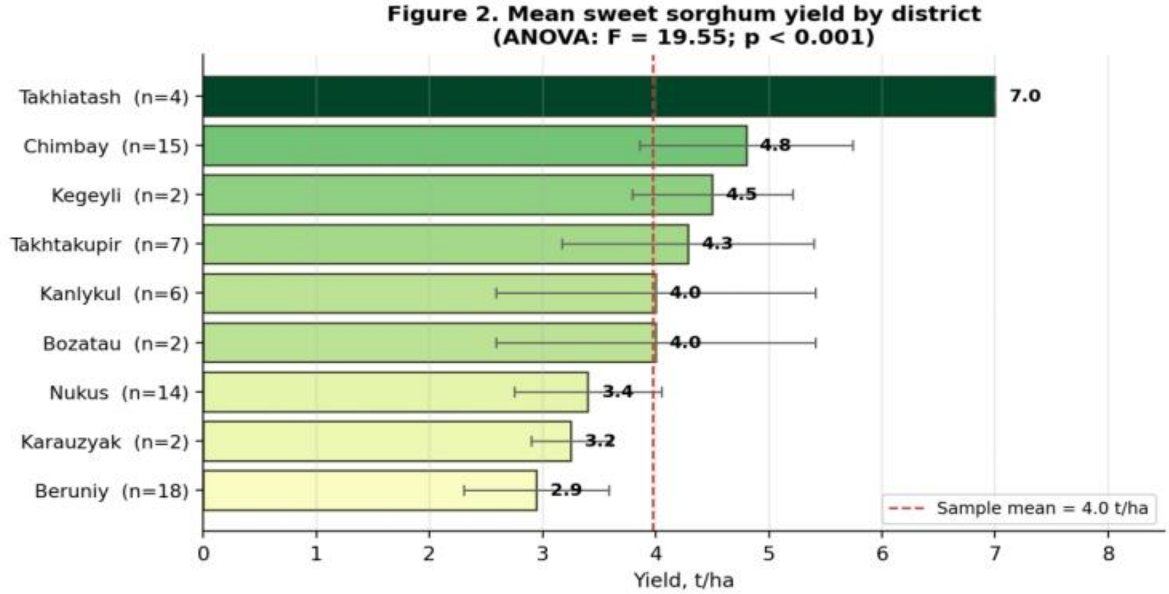

Figure 2 — Mean sweet sorghum yield by district (error bars denote standard deviation)

Correlation analysis showed a positive association of yield with sown area ($r = 0.36$; $p = 0.003$) and farmer age ($r = 0.25$; $p = 0.047$), and a borderline association with education ($r = 0.23$; $p = 0.056$) and experience ($r = 0.22$; $p = 0.069$). The negative association with the number of irrigations per season ($r = –0.31$; $p = 0.010$) indirectly indicates that more frequent irrigation is practised on saline, less productive plots. Economic indicators are given in Table 2.

Table 2 — Production and economic indicators of sweet sorghum cultivation (2025)

Indicator	n	Mean	Median	SD
Yield, t/ha*	70	4.0	4.0	1.3
Selling price, mln UZS/t	70	6.49	7.00	0.86
Revenue, mln UZS	72	236.4	162.8	208.4
Reported costs, mln UZS**	71	24.4	12.8	33.6
Post-harvest losses, %	72	10.5	10.0	—

** Excluding two extreme values (24 and 40 t/ha). ** Reported aggregate cash costs average only about 8% of revenue, indicating that mainly direct cash* *expenditures were recorded; for this reason the net-profit figure should be interpreted with caution and is not reported as a final result.*

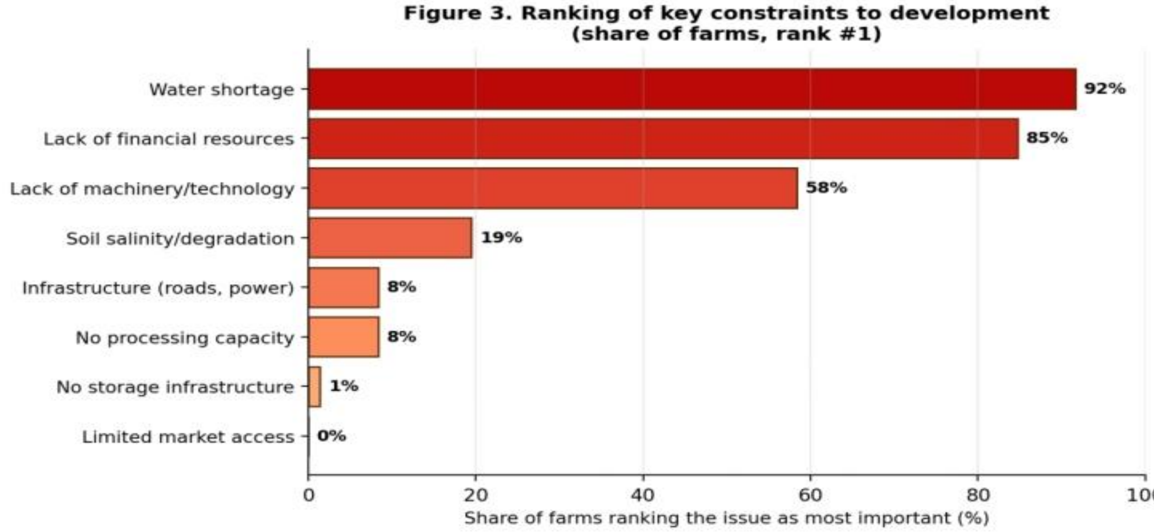

Figure 3 — Ranking of key constraints to development (share of farms ranking the issue first)

Structure of the value chain. Analysis of the chain's links revealed a markedly raw-material-oriented and weakly integrated structure (Figure 4). The overwhelming majority of farms sell the product unprocessed (78%); industrial or primary processing is entirely absent (0%). Marketing is carried out predominantly directly (96%) at the prevailing market price (96%), meaning that the farmer is a price taker and does not participate in value creation at subsequent stages. Irrigation in all farms is traditional, from canals (100%); water-saving technologies are not used. Membership in cooperatives and agro-clusters is absent (0%), and access to credit and state subsidies does not exceed 1.4%. At the same time, 96% of farms are covered by advisory services and market information, and 54% have their own storage. Average post-harvest losses amount to 10%.

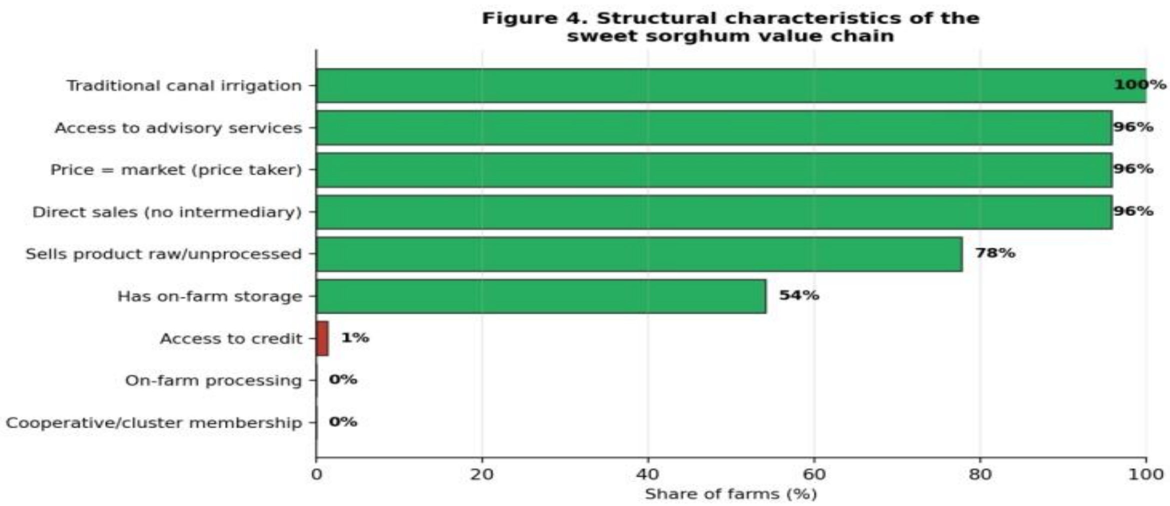

Figure 4 — Structural characteristics of the sweet sorghum value chain

Thus, value added is barely created within the region: the product leaves the farms in raw form, while the potential processing margin (syrups, bioethanol, fodder) remains unrealized.

Constraints to development. The ranking of problems by the farmers themselves (Figure 3) unequivocally brings irrigation-water shortage to the fore: 92% of farms identified it as the most important constraint. This is followed by a shortage of financial resources (85%) and the absence of modern machinery and technology (58%). Soil salinity and degradation were named as the top-priority problem by 19% of farms. The impact of climate change is felt by virtually all respondents (99%), with 48.6% rating it as moderate or strong.

CONCLUSIONS

1. Sweet sorghum in the Republic of Karakalpakstan is cultivated by narrowly specialized farms with a mean area of 7.4 ha; the mean yield is 4.0 t/ha and differs significantly among districts ($p < 0.001$), determined by soil-reclamation conditions and water availability.

2. The value chain is raw-material-oriented: 78% of output is sold without processing, processing and cooperation are absent, and 96% of farms are price takers at the market price. This deprives the region of a substantial part of the potential value added.

3. Institutional support is extremely limited: access to credit and subsidies does not exceed 1.4%, membership in cooperatives and clusters is absent, while post-harvest losses reach 10%.

4. The key constraints are a shortage of irrigation water (92%), a lack of financial resources (85%) and an outdated material and technical base (58%), against a background of intensifying climate-change impact.

5. Priority directions for the sector's development are: establishing primary sorghum-processing capacity (syrups, bioethanol, fodder); developing cooperation and agro-clusters to strengthen farmers' market position; introducing water-saving irrigation technologies and salt-tolerant varieties; and expanding access to credit and subsidy instruments.

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