Crop Rotation Current Practice and Decision-Making-A Case Study of Kumkurgan District, Uzbekistan

Abdivaitov, K.,[1,2*] Strobl, J.[1] and Hennig, S.[1]
[1]Department of Geoinformatics – Z_GIS, University of Salzburg, Schillerstraße 30, 5020 Salzburg, Austria
E-mail: khudoyberdi.abdivaitov@stud.plus.ac.at,* Josef.Strobl@plus.ac.at, Sabine.Hennig@plus.ac.at
[2]Department of Land Resources Management, "Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University ("TIIAME" NRU), Kari Niyazov 39, Tashkent 100000, Uzbekistan
**Corresponding Author*

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Abstract
Increasing global demand for food is a major challenge for many developing countries, particularly those in arid and semi-arid regions. It is the government's responsibility to address this significant issue locally. Sustainable use of irrigated agriculture plays a critical role in not only tackling local food security but also solving other related issues such as better water resource management, employment opportunities, livelihoods, climate change adaptation, and poverty reduction. However, land capable of being cultivated for crops is limited in Uzbekistan due to inappropriate use and management of natural resources, particularly land, water, and soil. Overuse or misuse of water in the past several decades has resulted in widespread land degradation across the country, exacerbating environmental problems such as the current water shortage, soil salinity, desertification etc. In this context, numerous potential measures should be carefully taken into account, such as implementing new approaches to current land use, agricultural land optimization for better allocation of available lands to crops or developing new methods for identifying potential areas for different crops. Therefore, the goal of this study is to investigate the current practice of crop rotation and to have a better understanding of crop allocation decision-making. Such analyses can serve as initial steps towards ultimately establishing a methodology for optimizing agricultural land allocation to specific crops.

Keywords: Agricultural Land Use, Crops, Crop Rotation, Land Allocation, Uzbekistan

1. Introduction

Agricultural land is an essential and the most valuable natural resource on the planet as it supports global food production, strengthens economies, helps reduce poverty, and contributes to rural livelihoods. With the rapidly growing world population, the need for sustainable management of agricultural land is increasingly urgent, presenting substantial challenges for scientists, policymakers, and other stakeholders in land management. FAO-initiated studies have revealed that the global cropland area per capita steadily declined, from approximately 0.45 hectares per person in 1961 to 0.20 hectares per person in 2021 [1]. Therefore, agricultural research is becoming significantly more important than ever due to the current global challenges in this sector including land degradation, climate change, water scarcity etc.

In Uzbekistan, agriculture is the predominant land use type and serves as the primary source of income for much of the population. Despite this country having a large land area of 448,924 km^2 and its rich, varied natural environment, only approximately 10 % of its land is suitable for farming. Most of the territory is arid or semi-arid, consisting of deserts and mountainous areas, which limits its suitability for agricultural production. Currently, Uzbek agriculture is facing several challenges: farmland suitable for cultivation is limited due to inappropriate use and management of natural resources, particularly land, water, and soil. Overuse or misuse of water in the past several decades has resulted in widespread land degradation across the country, exacerbating environmental problems such as the current water shortage, soil salinity, desertification etc. According to [2], the increased demand for irrigation water to support agricultural production has led to massive extraction of water from the Amudarya and Syrdarya Rivers, two primary rivers in this region. As a result, the ecological conditions around the Aral Sea have deteriorated. Thus, challenges have significantly impacted crop productivity and food security.

In this context, investigating ongoing agricultural land use policies and the process of land allocation for multiple agricultural crops is critical to enhancing agricultural productivity, and ensuring food security. With rapid population growth in the country and declining agricultural yields due to the above-mentioned challenges in this sector, the urgent implementation of new strategies for efficient agricultural land use, with a particular emphasis on crop rotation practices is required. Our study gives a brief overview of crop rotation practices and analyzes the key factors that decision-makers consider when suitable land for multiple crops in Kumkurgan District, presented as an exemplary case. Crop allocation decision-making processes play a pivotal role in meeting escalating food demands, especially in the face of climate change, rapid global population growth, and water scarcity in arid and semi-arid regions. The United Nations' Sustainable Development Goals (SDGs) guide responses to these global challenges towards achieving a sustainable future. Goal 2 (Zero Hunger), in particular, focuses on reaching a hunger-free world by 2030, and is directly linked to food security, nutrition enhancement, and the promotion of sustainable agriculture [3]. Agricultural land users are continually making vital crop allocation decisions. A common decision-making approach is to employ the principles of crop rotation [4].

Crop rotation on arable land is nothing new. In ancient Rome, Greece and China, farmers applied the practice of rotating crops on a given field, and in the Middle East farmers have rotated crops since 6000 BC [5] and [6]. Crop rotation means alternating crops in successive crop years in a planned sequence so that crops of the same species are not grown in the same field without interruption. The rotation is done in a regular cycle. The crops are usually changed annually, but they can also be rotated after multiple years. It is called biennial when two species are alternated from one year to the next, and triennial for three species, etc. There is no limit to the number of crops that are organized in a rotation system, nor the number of years that a rotation needs to complete. It is, however, commonly accepted that crops should be changed at least every five years for it to be considered a crop rotation system. Less frequent changes are associated with permanent (monoculture) crops or permanent grasslands. Another feature of crop rotation systems is that the successive crops must be from diverse plant families. That is, a given crop must be followed by one from a completely different taxonomic family (not just a different species) [5] and [7].

Crop rotation offers several benefits. For instance, crop rotation improves soil tilth, i.e. the chemical, physical and biological structure of the soil. This is because plants from different families have diverse root shapes and sizes, and the variety contributes to soil health [6]. Crop rotation reduces pest and disease pressure because changing the plants can disrupt the lifecycle of crop-specific pests and diseases. Furthermore, different plants provide and extract different types of nutrients from the soil. Consequently, rotating crops helps to minimize the depletion of a given nutrient. Together these benefits lead to increased crop yields while simultaneously reducing pesticide and fertilizer requirements. Finally, crop rotation increases biodiversity on the farmland. Thus, crop rotation is one of the most effective production techniques for maintaining soil health and increasing productivity [8][9][10][11] and [12]. Sustainability is an important topic for agriculture and three sustainability goals are presented in Table 1. Consideration of crop rotation systems is an important step towards achieving these goals. This is particularly so in the context of plant fiber cultivation for textile manufacturing [10]. As outlined in [13], in the case of sustainable fiber cultivation, a coexistent crop configuration seems a promising approach to raising cultivated biodiversity while at the same time improving income and living conditions for the local population [14]. It is important to rethink the design and implementation of agricultural systems, considering crop rotation and co-planting options, so that productivity is maximized while associated ecosystem and socioeconomic factors are improved [15]. Finding and deciding on optimal crop rotation strategies depends not only on agronomic parameters, but also on consideration of the socio-economic and agro-ecological facets of each production system [16].

Table 1: Long-term goals of sustainable agriculture (adapted from [17])

Long-term goal	Description
Quality of life	To satisfy personal, family, and community needs for health, safety and food
Environmental quality	To enhance soil nutrition, water, air, and other resources
Economics	To be profitable

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With respect to fibre cultivation – and specifically cotton – the following crop rotation systems are mentioned in literature [10][18][19] and [20]:

- cotton-wheat-maize,
- cotton-wheat-sorghum,
- cotton-wheat-soybean,
- cotton-alfalfa,
- cotton, peanut, grass,
- cotton, soybeans, corn,
- cotton, sorghum, wheat, or
- cotton, wheat.

Currently in Uzbekistan cotton – wheat crop rotation is common. This is not considered a good choice for optimum agricultural management practices, and it has been suggested that introducing legume crops into the rotation could help prevent further soil degradation [18]. Similarly rotating cotton with a sorghum grain crop has proven beneficial [11]. Research on the allocation of agricultural land to crops is an important task and should be tackled from the perspective that productive arable land is a limited resource. In Uzbekistan agriculture forms the basis of the national economy, and land use (and crop allocation) is centrally planned and managed by the government. Improvements to methodological workflows are urgently needed to best support optimized land allocation to multiple crops. Therefore, our objectives here are to:

1. Identify the key stakeholders involved in existing processes of cropping decision-making.
2. Better understand ongoing agricultural policies, and the information with which decision-makers base their choices of land allocation to crops, and the criteria for determining what crops are planted and where.
3. Investigate how recent policy developments on land use planning for agriculture influence centrally predetermined cropping patterns.

This study aims to understand crop allocation decisions, a critical step towards enhancing resource use efficiency at the farm plot level, including land and water management. It is important to understand the decision drivers used to guide crop selections as these decisions significantly influence agricultural production. Working towards improving methods used to allocate crops is a key step in achieving enhanced agricultural sustainability and productivity in Uzbekistan.

2. Materials and Methods

2.1 Farm Classification and Land Allocation

With numerous arid and semi-arid zones across the country, Uzbekistan's landscape comprises 80% plains, and 20% mountains and foothills, with 4,3 million hectares of irrigated land. Agriculture still plays a vital role in the Uzbek economy – most people live in rural areas and over a quarter of the labor force are employed in the agricultural sector. Several studies, for instance [2][21][22][23] and [24], have highlighted ways in which agricultural land could be used more effectively and sustainably. They have identified various factors that influence land use optimization via sustainable agricultural practices, such as promotion of soil health, and improved water management, crop selection, and environmental conservation measures. The need to implement adaptive and resilient agricultural strategies is particularly relevant given recent changes in cotton production under the emerging clusters and the impacts of climate change on farm income. Uzbekistan, with its vast potential of different land categories, has seen significant changes in land ownership policies. Most of the land belongs to the national government [25]. However, in September 2021 a new law, No. 728, titled "On privatization of non-agricultural land plots" was enacted. This law allows state-owned land not intended for agricultural purposes to be transferred to the ownership of citizens and/or legal entities of the Republic of Uzbekistan [26]. These recent changes in land ownership policies are crucial for understanding the evolving landscape of Uzbekistan's agriculture.

According to the current legislative framework on land use, agricultural land is used by two farm types with different land rights. The information presented in Table 2 includes recent changes to legislative acts regarding land use. Table 2 provides an overview of the main characteristics of the two farm types currently being operated. One important point to note is that land given for agricultural needs (or intended for this purpose) belongs to the national government. These two types of agricultural land users have different land rights according to the legislative frameworks governing land use. Figure 1 shows the number of private farms by the size of the cultivated land area. As shown in Table 2, farm size depends on production specialization. As outlined by [27], land tenure rights in Uzbekistan lack the essential attributes necessary for meaningful land use planning by tenure-holders. While the duration of these tenure rights is adequate, they fail to guarantee holders that their rights will be acknowledged and enforced at minimal expense. Additionally, they do not offer mechanisms enabling adjustment to changing conditions. Insufficient land tenure security, further undermined by state interventions, constitutes a substantial obstacle hindering agricultural sector development.

Table 2: Main characteristics of current farm types in Uzbekistan (adapted from [28] and [29])

Indicator	Farm types	
	Private farm (*farmers*)	*Dehkan* farm (small-scale household farms)
Basic definition	A business entity engaged in the cultivation of agricultural products using leased land and other types of activities not prohibited by law.	Small farming enterprises (an individual or family farm).
Average land plot size	It can vary with respect to production specialization: • for vegetable growing – the minimum is 3 hectares. • for horticulture, viticulture - the minimum is 3 hectares. • for cotton and grain growing - the minimum is 30 hectares. • for grain and vegetable growing – the minimum is 10 hectares. • for the cultivation of fodder crops • for those specializing in the production of livestock products (per conventional head of cattle) o from irrigated land - at least 0.3 hectares, o from rainfed area - at least 1 hectare, o from pastures and hayfields - at least 2 hectares.	Usually from 0.06 hectare to 1 hectare. To grow animal fodder crops for farming, land plots of 0.06 to 5 hectares are allocated in specific regions determined by decisions of the President.
Labor utilization	Family members, along with permanent and seasonal workers, are involved.	Primarily family members, with the option to hire seasonal laborers.
Land tenure	As of 1 March 2024, land plots will be leased for 30 years (previously between 30-50 years).	Lifelong inheritable possession or lease (secondary lease).
Land allocation procedure	Through electronic auctions	
Cropping structure	Futures contracts with any cluster within their region after abolition of the state-order system.	Own decision.
Production specialization	Agricultural production is restricted to the crops specified in the land lease contract, primarily cotton and wheat.	Horticulture, viticulture, vegetable cultivation or other agricultural crops.

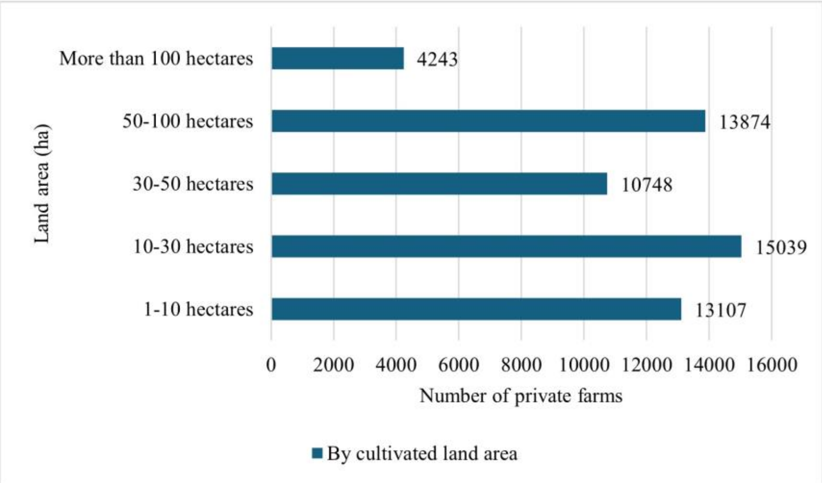


Figure 1: Distribution of private farms over cultivated land area

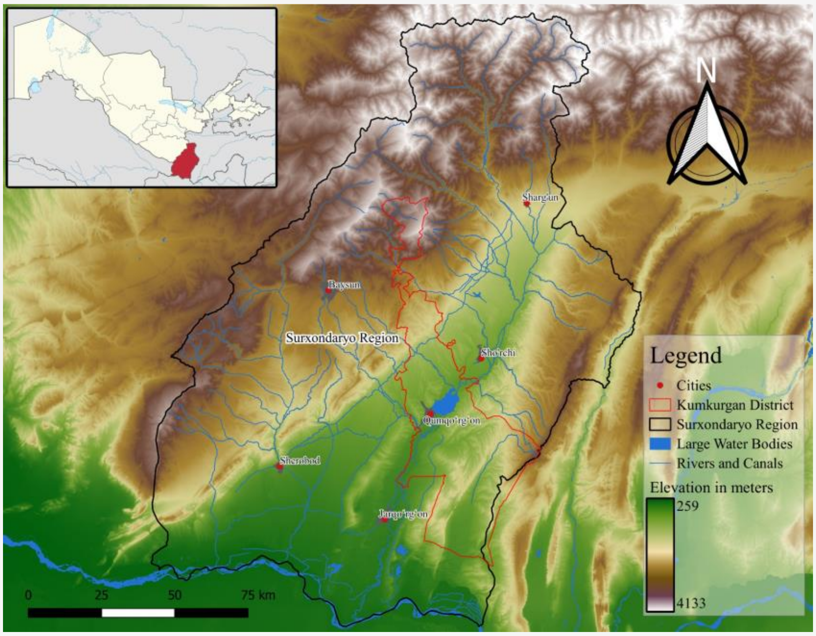


Figure 2: Digital Elevation Model (DEM) of Kumkurgan District, Uzbekistan

According to the national statistics report on republican land use, summarized by the Chamber of State Cadasters in 2024, Uzbekistan has a total of 261,322 km^2 of agricultural land representing 58.21% of its total area. Of this, 63.92 % is classified as rangeland, while only 43,425 km^2 of irrigated arable land accounts for 9.7% of the entire territory of the country. However, a small proportion of this land belongs to settlements for individual housing construction. Therefore, the actual sown area of agricultural crops is 32,451 km^2 [30]. Based on the availability of total cultivable land across administrative regions, the national administration centrally manages decision-making for agricultural production. Each crop type is spatially allocated at the farm plot level for the next year's harvest, considering national food security and the export potential of the regions. Traditionally, most of the irrigated areas are allocated for sowing cotton and wheat, the country's two strategic crops. Until recent years, under this system, farmers' lease contracts specified the exact areas to be sown, particularly for these major crops.

2.2 Study Area

Our case study area, Kumkurgan district, is situated in the central part of Surkhandarya province, which is located in the far southeast of the country (see Figure 2). The district is primarily focused on the agricultural industry and is among the most well-developed districts in terms of agriculture in Uzbekistan. It covers an area of 2,137.52 km^2, including 284.44 km^2 of irrigated land. The primary focus of agricultural activity in this district is the cultivation of cotton, fine-fiber cotton, and wheat. Kumkurgan is well known as a leading cotton producer not only within Surkhandarya province but also by comparison to the other 170 districts in Uzbekistan. A land suitability assessment model for cotton cultivation was implemented in this area in 2022 to evaluate and classify the suitability of land for this crop [31]. The agricultural sector in the district has, however, seen significant growth in animal husbandry, horticulture, sericulture, and vegetable cultivation. This area demonstrates the significant potential of the currently limited agricultural land through the ongoing production of exportable agricultural products.

2.3 Methodology

Our primary data were collected through interviews and surveys with diverse groups of experts like farmers and agricultural officials during the study. The survey included a variety of questions regarding crop types, current cropping and crop rotation practices, the process of selecting appropriate crops throughout the growing season, land tenure, water usage, and the factors influencing crop allocation decisions. Secondary data were obtained from governmental records, such as annual reports on land use, cadastral data, legislative documents, and previous studies on land use and agricultural practices in Uzbekistan.

Besides that, qualitative policy analysis was used for personal interviews with policymakers to understand the legislative framework governing land use and crop allocation. This involved reviewing recent laws and regulations, particularly Law No. 505, which was used to identify key stakeholders in land use planning for agriculture and the main criteria while allocating crops.

The legislation governing cadastral definitions defines the term "landmass" (can be also called a subdistrict). These landmasses comprise large areas of land that share common characteristics such as soil composition, terrain features, and climate conditions amongst other factors, and serve as units to guide division of territories into cadaster. Currently, there are fourteen agricultural landmasses in the Kumkurgan district where farms and land users operate. The State Unitary Enterprise "Soil Composition and Repository Quality Analysis Center" conducts soil quality assessments every five years on irrigated land and every ten years on rainfed areas. In 2022, this company conducted work within the case study area at each agricultural land plot level, producing soil bonitation maps at a scale of 1:10,000. Such maps are separately made for each landmass. Table 3 gives an overview of the current state of the soil in Kumkurgan district. Statistical figures reporting on agricultural production follow a "top-down" approach and are determined and reported at a national level. The figures are distributed among regions, districts, and individual plots within each landmass, based on cultivable land availability.

Table 3 shows the irrigated land quality classifications for each landmass alongside corresponding land area and average bonitet scores. Such data is crucial for decision-makers to accurately allocate crops at the plot level. As mentioned by [30], "the bonitet score is conducted relative to cotton yield of the best soil quality in Uzbekistan, (e.g., cotton yield of 0.04 tons per 1 bonitet score and wheat yield of 0.06 tons per 1 bonitet score). Thus, the classes 1-4 are lands that need amelioration and remedial actions to be undertaken for improving the soils." The soil assessment data in Table 3 is a key input to crop allocation decision-making processes. Within each landmass the final allocation decisions at the plot level are primarily based on that soil quality and water availability data. As indicated in the table, the average bonitet score is 54.8, with most irrigated lands scoring between 41 and 70 points. These values are relatively low, and regrettably, the official average bonitet score is calculated at a national level. Over recent years the average bonitet score for the Kumkurgan district has decreased due to several factors, including the cropping system (Figure 3).

Table 3: Quality assessment of irrigated soils in the Kumkurgan district

Landmass name	**Classification of soil according to the level of fertility**							**Total irrigated land area**	**Average bonitet score, 2022**
	Below average	**Average**		**Good**		**Best**			
	IV	**V**	**VI**	**VII**	**VIII**	**IX**	**X**		
	Bonitet* Score								
	31-40	**41-50**	**51-60**	**61-70**	**71-80**	**81-90**	**91-100**		
Komolot	11.8	367.8	365.8	157.5				902.9	53.4
Saykhon		208.3						208.3	44.6
Kh.Baratov			73.3	129.7				203.0	63.2
Sh.Mirzaev		177.5	605.6	643.2		48.9		1,475.2	58.8
Navruz	226.5	284.3	234.9	206.8				952.3	51.2
South Surkhan reservoir	104.5	166.9	249.2					520.6	48.4
State reserve lands		29.9	51.6					81.5	50.3
Korakulcha		345.4	120.8	6.1				472.3	49.6
Okkopchigay		13.8	627.7	445.3				1,086.8	58.4
Uzbekistan	3.4	798.4	297.6	1,473.2	24.2			2,596.7	58.5
Kumkurgan		636.1	675.3	1,031.5				2,342.8	55.8
Beshkhramon	57.5	480.6	678.5	1,060.0	238.5			2,515.1	59.1
N.Mirzaev		82.7	1,230.3	1,144.3	337.4			2,794.7	60.5
S.Boymatov	9.7	2,153.9	2,443.2	833.4	762.1			6,202.3	55.5
Total by district	**413.4**	**5,745.4**	**7,653.7**	**7,130.8**	**1,362.2**	**48.9**		**22,354.39**	**54.8**

Note: *I-II (Bad) and III cadastral groups are not shown in the table as they contain no areas. *Government officials utilize bonitet to categorize land into classes according to its potential productivity and quality. This classification is then used to establish annual production targets for farms.

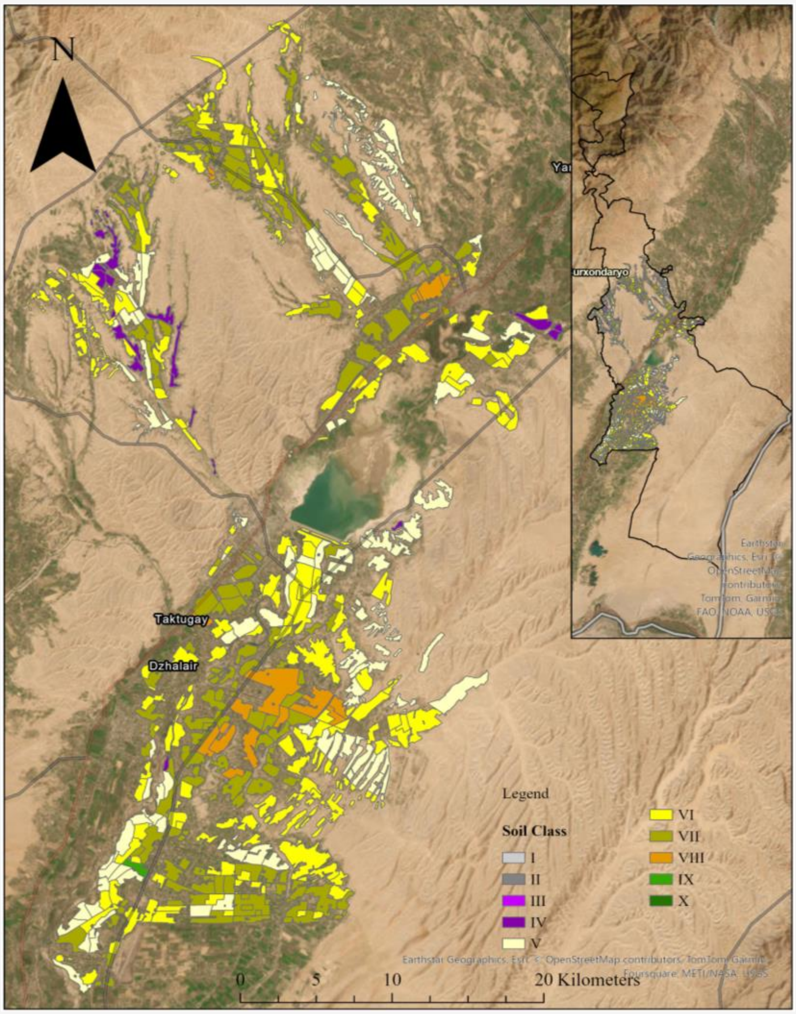
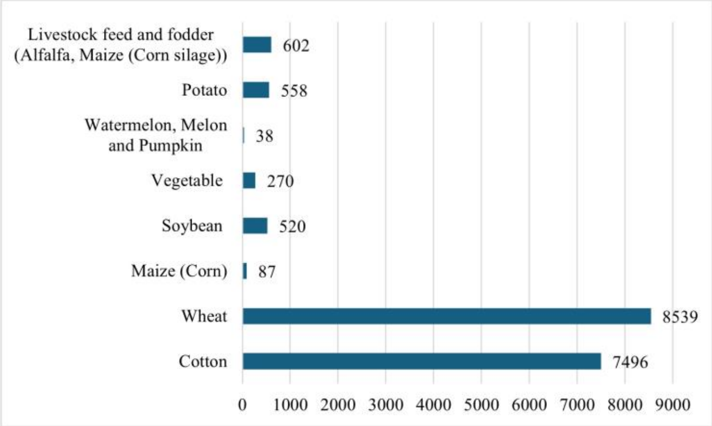


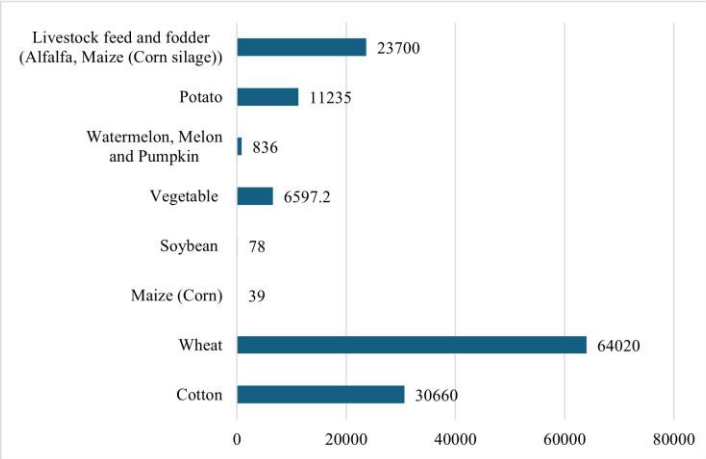
Figure 3: Spatial distribution of irrigated soil class in the Kumkurgan district

Owing to state land ownership and centralized agricultural planning, the cultivation of two major cash crops - cotton and wheat - has predominated across most of the cultivated areas for many years. Unfortunately, due to data accessibility restrictions, we could only obtain crop allocation data at the farm plot scale for 2023. This limited data, while providing a snapshot of the current practice, does not fully capture the dynamic nature of the decision-making process, which can vary from year to year. Initially, resolutions are issued by the Cabinet of Ministers of Uzbekistan. Subsequently, governors of provinces, districts, and cities determine which crops are to be cultivated on local farm plots. According to the resolution made by the governor of Kumkurgan district on “Indicators for allocating agricultural crops to cultivated areas in the district in 2023”, 7,496 hectares of cotton and 8,539 hectares of wheat were planted over a total cultivated area of 18,142 hectares (Figure 4). These two crops dominated the district and accounted for 88,39 % of the crop-capable land. This scenario repeats every year, highlighting the government’s specific emphasis on allocating the majority of cultivated areas to cotton and wheat production. Additionally, this cotton and wheat allocation dominance is repeated at a national scale. The process of allocating land to crops is strongly influenced by centralized government planning. Law No. 505 issued by the Cabinet of Ministers of Uzbekistan, titled “About the approval of the regulation on the order of rational allocation of agricultural crops” serves as a main legal foundation of current government policy on agricultural land use practices. This crop allocation example shows how much farmers must harvest enough cotton, wheat or other crops to fulfil the government-imposed quota (Figure 5).



Area (ha)

Figure 4: Crop cultivation areas in Kumkurgan district in 2023



crop yield (tons)

Figure 5: Intended crop yield of the plants

The potential for crop production in much of the region has been severely constrained by factors such as declining soil fertility, decreasing water availability, and climatic conditions characterized by hot, dry summers and cold winters. Consequently, farmers often face challenges in meeting their quotas. In case of not meeting the quota, the farmer must refund the loan from income earned from other crops or in the subsequent year. To achieve the intended crop yields, implementing national agricultural policies is managed territorially, through provincial and district governors. If the farmer cannot meet the quota for three consecutive years, the government takes land and subsequently reallocates it to another farmer through an electronic online auction.

3. Results

Decisions regarding the allocation of land resources to various uses, particularly for specific crops, are crucial for successful land use planning and zoning. Allocating the most suitable areas for different crops is especially important for enhancing agricultural sustainability and productivity. Identifying the best plots of available farmland with sufficient capacity for cultivation is essential for local decision-makers. These important and complex spatial decisions typically involve evaluating numerous feasible alternatives based on multiple criteria. Criteria can be categorized into two types: factors and constraints [31]. Based on our research and experts' opinions, various agricultural land suitability factors (i.e., land use/cover, soil related factors: major soil type, texture, depth, moisture, stoniness, erosion, pH, topography factors: slope and elevation, climate conditions factors: temperature, precipitation and proximity factors: to road and to a water body) should be employed to make recommendations for the best plots for specific agricultural crops in Uzbekistan. Figure 6 provides an overview of the main criteria that should be considered when allocating agricultural crops.

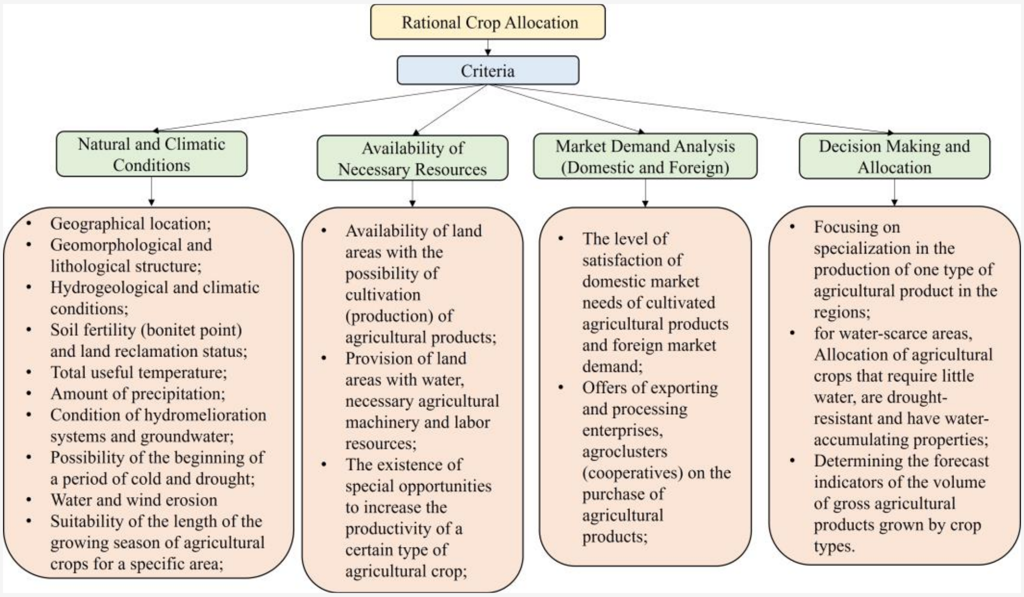


Figure 6: Criteria used for rational placement (allocation) of agricultural crops in Uzbekistan (**Source:** Resolution of the Cabinet of Ministers of the Republic of Uzbekistan dated 08/24/2020, No. 505 "On approval of the regulations on the rational placement of agricultural crops")

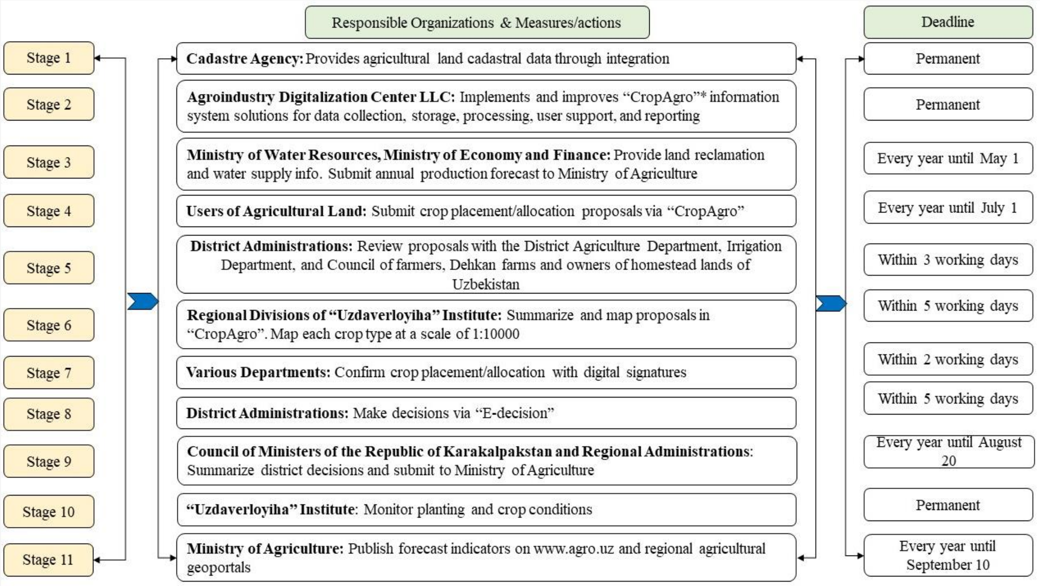


Figure 7: Modified after Resolution No. 505 - The scheme for the implementation of work on the rational placement of agricultural crops (*Source:* Resolution of the Cabinet of Ministers of the Republic of Uzbekistan dated 08/24/2020, No. 505 "On approval of the regulations on the rational placement of agricultural crops")

From the authors' point of view, there is a need to develop better land use allocation approaches. For example, [31] attempted to address the complexities of land allocation decisions by analyzing multiple criteria and offering new decision support tools developed for raster GIS data handling, specifically within the IDRISI geographic analysis software system. GIS-based decision support tools are often used to assist in decision-making, and the research has shown that such tools can be used particularly for solving land allocation problems. The authors clearly stated the development of GIS as a decision support system – a means for deciding how to perform the analysis produced [33]. As a schematic workflow, Figure 7 presents a concise summary of the current crop allocation process.

Figure 8: Field trip to the study area

Measures/actions are distributed among responsible organizations. This figure is a simplified version of the whole scheme and provides a summary of the current situation about how land allocation (and crop allocation) is done. During a field trip to the Kumkurgan district in August 2023 interviews were conducted with farmers (Figure 8). The purpose of the interviews was to determine what decision-making methods farmers are using to guide crop cultivation at a farm plot level. Our main findings from these interviews are as follows:

i) Farmers know how best to distribute crops on their land, having extensive experience regarding the soil conditions. However, despite having options to allocate crops to plots, they must follow state plans.
ii) Farmers sometimes face challenges due to contradictory land legislation, which impedes their use of all purported land rights.
iii) A lack of available irrigation water during the crop growing season is a significant constraint to achieving planned yields.

4. Discussion

The results of this study indicate that Uzbekistan's land use is primarily governed by the state authorities at both central and local levels. The state owns all agricultural land and prioritizes the cultivation of crops critical to the national economy, particularly cotton and wheat. In terms of the institutional framework for land use, a diverse group of stakeholders – including ministries, regional agricultural departments, institutions, decision-makers, farmers, dekhkans, and households – is involved. These actors undertake various activities and play different roles in determining optimal crop allocation strategies. Uzbekistan initiated a clustering policy in the national cotton sector in 2018. With Presidential Decree No. 4633, issued on March 6, 2020, mandatory production targets were abolished. However, the crop allocation policy still remains, leaving farmers with no choice in deciding whether to grow cotton [22]. Agriculture in Uzbekistan is impossible without irrigation. The transboundary rivers Amu Darya and Syr Darya are the primary sources, together providing 82% of Uzbekistan's total irrigation water demand. By contrast, the internal rivers Kashka Darya, Zarafshon Darya, and Surkhan Darya provide the remaining 18% of the irrigation demand. Surface water supply in Central Asia is heavily dependent on winter and spring precipitation, as well as snowmelt from the Tian Shan and Pamir mountains [30]. Efficient land allocation to crops is a complex task and one key component is water availability. Decisions about irrigation water allocation are often based on approximate calculations of reservoir levels across the country. These calculations form the basis for decision-makers' plans to distribute irrigation allocations across different regions, which in turn governs which crops are grown were. Our study offers a concise overview of the current crop allocation situation so that opportunities to do things better can be identified. We present a recent policy perspective as well as a local farmer perspective to understand how crop allocation is approached at administrative scales and the practical farmer level.

5. Conclusion and Outlook

The results presented here show that there is a need to introduce more diverse crop rotations, especially innovative approaches to land allocation, to mitigate soil degradation and enhance sustainability. The study identifies a deficiency in methodological workflows to support optimized land allocation for multiple crops in centrally planned agricultural systems. Our findings indicate that the current use of geographic information system (GIS) data analysis to improve resource allocation, particularly for agricultural crop allocation, is insufficient and often lacking.

By contrast it is suggested that land suitability analyses can benefit from the inclusion of relevant GIS and earth observation (EO) datasets. Given the comprehensive coverage of EO datasets such as Sentinel-1 and Sentinel-2 it is possible to use this data alongside existing national spatial datasets to evaluate crop suitability for the entire nation. Such an evaluation would help determine which regions are suitable for various land use purposes, enabling the identification of optimal plots, patterns, and rotational sequences for agricultural crop production. Irrigated areas in Uzbekistan have not yet been evaluated using Sentinel-1 and Sentinel-2 data to determine their land use suitability. Doing so could aid more efficient management and utilization of agricultural land. In practice, lands allocated for cotton and wheat cultivation could yield higher productivity if reallocated to other crops. Currently farmers are not able to make these changes (despite being aware of the potential benefits) because they are constrained by governmental regulations that prevent crop reallocation. Given these constraints, better methods for governmental agricultural crop allocation are required. The implementation of GIS and mathematical optimization-based decision-making approaches offer achievable workflows that can serve to enhance agricultural sustainability and productivity in Uzbekistan. Overall, taking into account Uzbekistan's strong agricultural potential farmland for specific crops could be better allocated concerning climate bio-physicochemical characteristics of the land to help address the above issues. Lessons learnt from such a local area can be critical for other regions facing similar issues, supporting more general insights beyond the extent of our study area.

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