Agricultural Land Use Dynamics - A Case Study of Kumkurgan District, Uzbekistan

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Abstract
In recent years, many investigators started using global land cover data sets for a variety of purposes. ArcGIS Living Atlas of the World offers access to a collection of geographic information from around the globe to perform different analyses including monitoring the status of agricultural lands. Timely and reliable Land Use and Cover Change information can be used for a better understanding of the dynamics of agricultural land use. Therefore, this research aims at analysing agricultural land loss or expansion in Kumkurgan district, Uzbekistan, using openly available global land cover data sets. Using high-resolution, open, accurate, comparable, and timely global land use/land cover data plays a critically important role in enabling dynamic change analysis. Such analysis has a remarkable impact, particularly for agricultural lands with the aim of their more effective use and addressing the ongoing demand for other land use types. In addition, these maps support agricultural land allocation decisions and further land use planning for sustainable development as well. We performed agricultural areas change analysis leveraging data from the Living Atlas infrastructure between 2017 and 2022, using ArcGIS Pro. To compare the results achieved from globally available online data sets, national summary statistics data on agriculture provided by the Chamber of State Cadastres was used. Our findings indicate that due to hilly terrain, the availability of valuable cropland is limited in comparison to other agricultural land use types like rangeland within the entire study area. Due to state land ownership and centralised planning, mostly two major cash crops - cotton and wheat - are cultivated in these areas. This research is intended as a baseline for ultimately establishing a methodology for the optimisation of agricultural land allocation to specific crops.

Keywords: Agricultural Land, Geographical Information Systems (GIS), Land Cover Change, Uzbekistan

1. Introduction

Due to ongoing political conflicts in certain areas of the world today, the matter of most effectively using available agricultural land has become increasingly crucial. The United Nations Sustainable Development Goals (SDGs), particularly Goal 2 aims at creating a world free of hunger by 2030. Since 2015, the number of people facing hunger and food insecurity has increased with the pandemic, conflict, climate change, and growing inequalities exacerbating the situation. To achieve zero hunger by 2030, immediate coordinated action and policy solutions to address entrenched inequalities, transform food systems, invest in sustainable agricultural practices, and reduce and mitigate the impact of conflict and pandemic on global nutrition and food security are required [1]. In this context, agricultural research has emerged as an urgent mission, particularly in semi-arid regions with limited water supply and countries with agriculture-based economies. Uzbekistan can be clearly stated as such country characterized by high mountain regions as well as hilly terrain and floodplains, where a significant portion of the population resides and lives off in rural areas.

Thus, our primary objective is to conduct an analysis of how much agricultural areas change, serving as a baseline assessment to propose further recommendations towards a fuller use of the agricultural potential by using geospatial data and methods.

Human-induced land use/land cover (LULC) change has had a profound impact on ecosystems globally over the last several decades [2]. These significant impacts span from local to global scales. Human well-being is mostly dependent on Earth's natural systems [3]. Extracting and examining these shifts and their implications for the agricultural sector of the study area offer numerous advantages. For instance, such analysis facilitates continuous monitoring by satellite-based global datasets, providing valuable information to support informed decision-making concerning land use and management practices. It is essential for the effective management of agricultural land to address the ongoing demand for other land use types. Moreover, the findings from this analysis can provide evidence to stakeholders and decision-makers to promote responsible actions.

In recent times, a diverse range of online land cover services based on full and regular remote sensing coverage with automatic extraction of LC through machine learning approaches has become accessible to users. Moreover, they are complemented by geospatial cloud computing capabilities, offering researchers the opportunity to conduct analyses at the original (sensor) resolution. Furthermore, these services are integrated with geospatial cloud computing facilities, providing researchers the ability to leverage analyses at the original sensor resolution. The primary advantage of this approach is that researchers can conduct analyses without the need for data download, pre-processing, and local computational resources. This innovative approach was first implemented in Google Earth Engine [4]. During the past twenty years, numerous global land cover (GLC) maps have been generated by employing remote sensing data, with ongoing advancements geared towards achieving higher spatial resolution datasets. GLC datasets continue to hold essential significance as primary inputs for scientific communities, non-governmental organizations (NGOs), private initiatives, and governments [5]. Observing land cover at the global scale is vital for leading to a better understanding and monitoring of global transformations [6].

Land use/land cover (LULC) maps are being widely used as foundational geospatial data products by diverse groups of people like analysts and decision-makers across governments, civil society, industry, and finance. These maps have numerous advantages, serve as critical tools for monitoring worldwide environmental change, and measure risk to sustainable livelihoods and development. There is a significant demand for high-level, automated geospatial analysis technologies that convert these pixels into actionable information for non-geospatial experts. Because of their high spatial, spectral, and temporal resolution, the Sentinel 2 satellites, which were launched in mid-2015, the second in 2017, are open data sources for LULC mapping. Deep learning and scalable cloud-based computing advances have now enabled the analysis capabilities needed to unlock the value in global satellite imaging observations [7].

Although satellite images are not directly analysed in our study, we relied on a ready-to-use imagery and derived LULC layers at 10m resolution available inter alia through Esri's Living Atlas cloud infrastructure (https://livingatlas.arcgis.com). It is an evolving collection of curated and authoritative geographic information from around the globe including easily accessible numerous land cover data as an image service with a query. As stated by [8], 'Nowadays, there are many sources of Land Use Cover (LUC) data. The availability of LUC data has been increasing since the end of the last century, in line with the development of remote sensing techniques and easier access to aerial and satellite imagery. LUC data is available at all spatial scales, from local to global. Access to spatial information, including LUC datasets, has also improved in the last decade with the development of the open access culture'. These datasets can be used for various purposes depending on the specific objectives of the projects. For the first time, [9] presented a cross-comparison and accuracy assessment of Google's Dynamic World (DW), ESA's World Cover (WC), and Esri's Land Cover (Esri) products in order to inform the adoption and application of these maps going forward. They discovered that Esri had the highest overall accuracy (75%) compared to DW (72%) and WC (65%) by using global ground truth data with a minimum mapping unit of 250 m^2.

A total of 58.44% of Uzbekistan's land area is used for agricultural purposes, highlighting the critical role of this sector in the country's economy and food production systems. However, due to water scarcity and several other factors, the proportion of irrigated farmland remains limited, accounting for only 9.66% in comparison to other land use types. As a type of agricultural land, arable land consists of irrigated and rainfed areas. 'In Uzbekistan, the rainfed area covers more than 7,684 km^2 with rainfall exceeding 200 mm per year, yielding between 0.8 and 2.0 tonnes of grain per hectare' [10]. Such farming is also of great economic importance because it allows the use of lands that are inconvenient for irrigation. For that reasons, valuable farmland has become a limited resource in the country.

The most noticeable aspect of the statistic mentioned above is that non-irrigated agricultural land is dominant in comparison with the availability of irrigated agricultural areas. Considering the high demand for food by the growing population, there is a need to import food. According to Statistics Agency, in January-November 2022, Uzbekistan imported food products worth 3.2 billion US dollars from 109 countries.

2. Materials and Methods

2.1 Study Area

In this study, Kumkurgan district in Uzbekistan was chosen as a study area mostly specialised in agricultural activities. It is located in the central part of Surkhandarya province (Figure 1) and covers an area of 2,137.52 km² including 284.44 km² of irrigated land. It has a rich topography consisting mainly of hills, the Surkhandarya valley gradually rises to the west (towards Sherabad - Sarikamish mountains) and to the east (towards Bobotog) [11]. The climate is a dry subtropical climate. Winter is warm and short; summer is hot and long. The average temperature in January is 3°, the lowest temperature is -20°, -22°. The average temperature in July is 30°, the highest temperature is 48°. Average annual temperature is 16°. Average annual rainfall is 190-200 mm. Furthermore, because the location of Surkhandarya province is in the extreme southeast of the country, the district experiences a hot climate with approximately 235-240 sunny days per year [12].

The primary source of income for most of the population relies on agricultural production. Owing to the current land allocation policies of the state, a significant portion of the agricultural irrigated lands is dedicated to cotton and wheat cultivation, while non-irrigated agricultural land is utilized for livestock farming and horticulture. The agroecological conditions of the existing irrigated agricultural lands within the district are vary significantly. Particularly, Kumkurgan district demonstrates great potential for cotton cultivation, offering seasonal employment opportunities for the rural population. On an annual basis, the district typically allocates an average of 70-80 km^2 for cotton cultivation, subject to the state order [12]. To explore the potentials for land use improvements, unfortunately finding GIS and remote sensing studies specifically focusing on land categorization within the study area is challenging.

Currently, the lands in the study area have not been evaluated using Earth observation data from Sentinel-1 & 2 for land use suitability purposes.

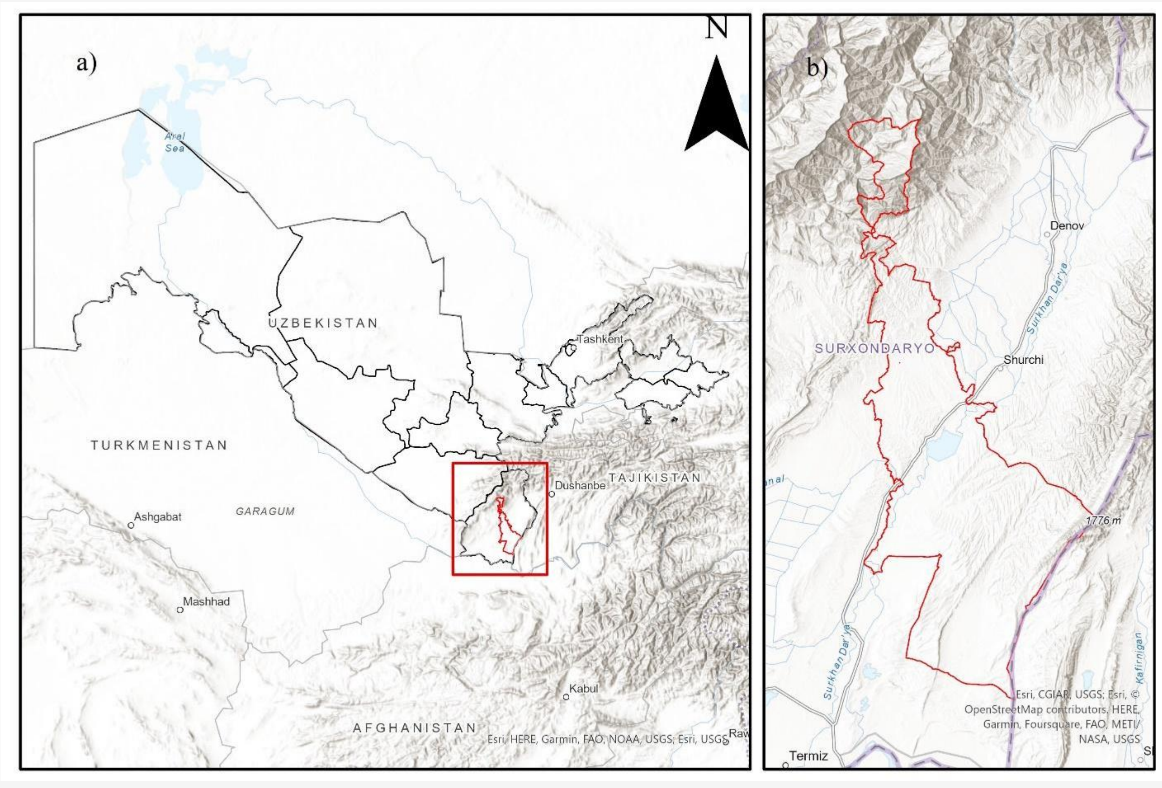

Figure 1: Location of the study area with a topographic view, a) location of Uzbekistan; b) research conducted area (Kumkurgan district)

There is a need to analyse the usefulness of these lands using applications of geographic information systems and Earth observation data. Further efforts are essential to enhance the extensive utilization of modern GIS and remote sensing data in assessing, observing, and analysing various land features in Uzbekistan. Any sustainable development in all fields should balance preparing highly qualified experts, accessibility to state-of-the-art information resources, and the implementation of effective policies in the country [13].

2.2 Data Used and Results

For analysis of LULC distribution and monitoring of recent changes, a change matrix was created by using a global LULC data set derived from ESA Sentinel-2 imagery at 10m resolution to detect major shifts of every class for years 2017 and 2022 (https://arcg.is/1L4aL9). Such an analysis can be helpful in further decision-making processes for regional development. This method was applied using ArcGIS Pro and the function of Pivot Table in Excel (Figure 2). LULC conversion matrix values were presented in terms of percentages (Table 1). The analyses were conducted using the UTM Zone 42 coordinate system. The change matrix analysis shows that as a whole, the conversion of bare ground and flooded vegetation to rangeland was substantial. For instance, 8,506.8 ha (72.14%) of bare ground and 4,135.3 ha (11%) of crops were converted into rangeland. 3,887.73 ha (10.34%) of crops changed into built area. In this instance, taking into account the difficulty of converting from non-agricultural uses to agricultural purposes, such changes in valuable farmland as a result of being occupied by settlements or other purposes cause further pressure on decreasing of these areas. Moreover, as mentioned most individuals are employed in the agricultural sector. To check matches between these datasets, a change layer called the Sentinel-2 10m Land Use/Land Cover product was used (https://arcg.is/1XDGXO).

This layer displays changes in pixels. This change matrix also provides information about conversions of different land use and land cover categories within the study area between 2018 and 2021 (Table 2).

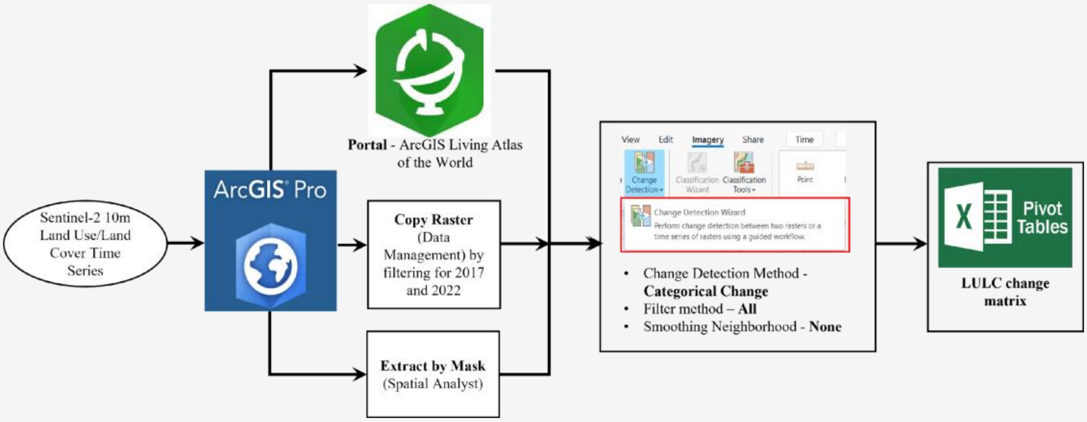

Figure 2: Graphical summary of generating LULC conversion matrix

Table 1: Summary of LULC change matrix in % between 2017 and 2022

LULC Classes		**2022**							
		Bare Ground	Built Area	Crops	Flooded Vegetation	Rangeland	Trees	Water	**Total area (ha)**
2017	Bare Ground	22.41*	0.08	1.45	0.00	72.14	0.00	3.93	11,792.71
	Built Area	0.31	97.76	0.96	0.00	0.93	0.00	0.04	12,037.45
	Crops	0.20	10.34	77.22	0.00	11.00	0.00	1.24	37,591.76
	Flooded Vegetation	0.00	0.00	17.74	19.35	62.90	0.00	0.00	0.62
	Rangeland	0.04	0.17	0.44	0.00	99.12	0.02	0.20	166,743.18
	Trees	0.00	0.88	0.70	0.00	37.01	61.41	0.00	291.97
	Water	0.52	0.77	4.78	0.04	0.78	0.00	93.11	2,176.08
	Total area (ha)	2,838.41	15,976.3	30,153.77	1.92	178,148.85	215.58	3,298.93	**230,633.76**

*Note: *Areas that remained unchanged in selected years are shaded*

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Table 2: Summary of LULC change matrix in % between 2018 and 2021

LULC Classes		2022							
		Bare Ground	Built Area	Crops	Flooded Vegetation	Rangeland	Trees	Water	**Total area (ha)**
2018	Bare Ground	54.23	0.43	1.28	0.00	43.88	0.00	0.17	22,983.58
	Built Area	0.04	96.63	2.72	0.00	0.55	0.00	0.06	13,642.18
	Crops	0.31	5.04	92.10	0.00	2.15	0.03	0.37	31,539.99
	Flooded Vegetation	0.00	0.00	29.28	19.41	5.92	45.39	0.00	4.85
	Rangeland	3.19	0.36	1.08	0.00	95.29	0.04	0.04	162,610.74
	Trees	0.00	0.02	5.65	0.00	46.57	47.46	0.00	220.22
	Water	16.74	0.34	3.98	0.04	2.88	0.00	76.03	2,302.03
	Total area (ha)	18,134.44	15,459.53	31,569.44	1.95	165,961.82	190.06	1,986.34	**233,303.59**

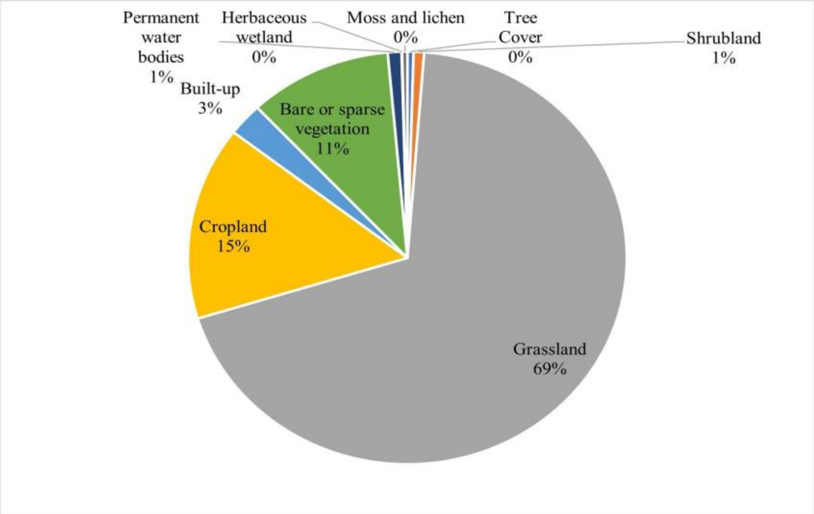

Figure 3: Land Cover categories within Kumkurgan – are dominated by grassland, cropland, and bare or sparse vegetation, with minor percentages of built-up, permanent water bodies, shrubland, and others

In this matrix, we can see from bare ground and flooded vegetation to rangeland has significant conversions of classes as well. For instance, with 43.87% of bare ground and 44.54% of flooded vegetation were converted into rangeland. 5.05% of crops changed into built area. Accordingly, such similarities in results will increase the reliability of global datasets. Another global dataset by European Space Agency (ESA) named WorldCover for the year 2020 (https://arcg.is/1uD9Lr1) containing 11 different land cover classes at 10 m resolution was tested to see changes and usefulness for the study area (Figure 3).

According to Article 43 of the Land Code of the Republic of Uzbekistan, agricultural land consists of arable land, hayfields, pastures, and land occupied by perennial trees (gardens, vineyards, orchards, orchards, etc.) [14].

We retrospectively analysed agricultural land types within the study area using yearly published government data as an annual report compiled by the Chamber of State Cadastres of the Cadastre Agency under the Ministry of Economy and Finance of the Republic of Uzbekistan (Figure 4). The stacked chart below presents a comparative analysis of agricultural land types within Kumkurgan district from 1992 - 2022. The chart clearly shows that total agricultural land occupies an average of 155,235.4 ha or around 77.8% of the total district area. However, most of the areas of these areas belong to permanent pastures, which are primarily used for grazing livestock. The proportion of (‘arable’) cropland accounts for only 18,818 ha in 2022 and it is 8.8% of the whole entire study area. Orchards and vineyards make up the smallest portion with 4,075 in 2022, representing 1.9% of the district area.

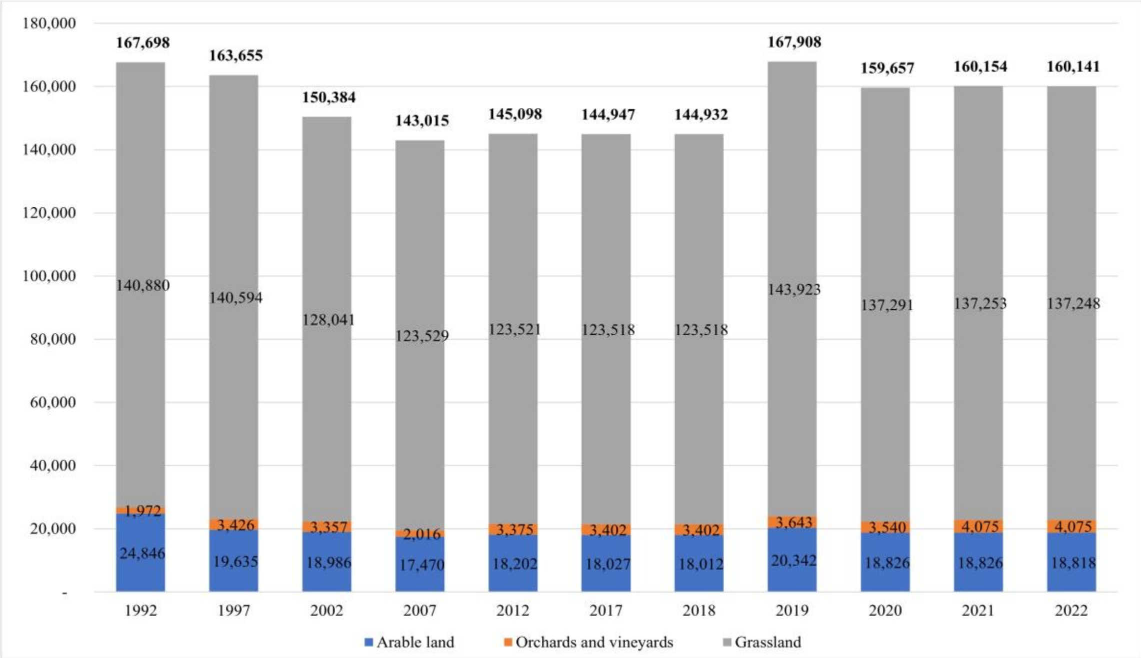

Figure 4: Dynamics of agricultural land use in 1992-2022 in hectares

The expansion of grassland areas in 2019 resulted in an increase in total agricultural lands. In this instance, taking into account the difficulty of converting from non-agricultural uses to agricultural land, such minor proportions of valuable farmland might be under pressure by occupying settlements or other purposes. Moreover, as mentioned most individuals are employed in the agricultural sector.

3. Discussion

By taking into account current major challenges in Uzbekistan including land degradation, water scarcity, and ongoing loss of fertile land, these accurate maps play a crucial role in better land use planning for agriculture. As in Central Asia, and specifically in Uzbekistan, land use occurs within a challenging environment impacted by arid climatic conditions. This gives rise to conflicts and collaborations between the forestry and agricultural sectors, with livestock playing a crucial role. Unfortunately, overuse or inappropriate use of natural resources such as soils, forests, rangelands, and, most notably, water resources has resulted in extensive land degradation across the region (FAO, 2023). The usage of agricultural land is essential to Uzbekistan’s economy and many other countries of the world, particularly in developing countries [15]. Agriculture can be considered one of the prime sources of income for the population in this part of the world [16]. Due to the practice of ‘sprawling’ urban development, agricultural land is under constant pressure. In this case, it is important to address how to solve land-use allocation problems among several types of land use [17]. Proper land-use allocation makes it possible to conserve as much agricultural land as possible. The results of this study can be used for a better understanding of the proximate causes of changes. Furthermore, such information is helpful for decision-makers, planners, and researchers to make informed choices for sustainable land management and conservation strategies. Monitoring the change in agricultural land using openly available global datasets at the district level can be used for further steps of the research.

4. Conclusion

The results presented here highlight the usefulness of global datasets identifying changes in agricultural land use types in Kumkurgan. Results were then compared to national land use data on agriculture in this district of Uzbekistan over a period of 30 years. Our findings reflect that readily accessible land cover archives and data products are enabled to perform baseline analyses. Our analysis demonstrates that arable land areas have slightly decreased as a result of mainly converting into settlements and other land uses. This study is a first step to assess from an agricultural perspective the usability of online land cover services. In addition, there is a need to establish a comprehensive knowledge base on the extent of land degradation, the drivers for land use changes, and the potential of integrated land use management.

This knowledge will empower policymakers and land resource managers to design policies and programs aimed at addressing the problematic impacts of agricultural land use on the environmental, economic, and social dimensions of sustainable development.

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