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Collect Earth ile Bölgesel Arazi Kullanımı Değerlendirmesi: Azerbaycan'ın Ağdaş Vaka Çalışması

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Öz

Periyodik arazi kullanımı ve arazi kullanım değişikliği değerlendirmeleri, etkili arazi kullanımı planlaması ve yönetimi için arazi kullanım kategorilerinin toplam alanını ve bu alanlarda zaman içindeki değişimlerini izlemektedir. Collect Earth, orman alanları, tarım arazileri, meralar, sulak alanlar, yerleşim yerleri ve diğer alanlar gibi arazi kullanım kategorilerindeki eğilimleri izlemek için geliştirilmiş ücretsiz erişimli bir yazılımdır. Bu çalışma, Azerbaycan'ın Ağdaş bölgesindeki tüm arazi kullanım kategorilerinin alansal değişimlerini rapor ederek, Google Earth platformundaki çok yüksek mekânsal ve zamansal çözünürlüklü uydu görüntülerinin görsel yorumlanmasıyla 1.116 adet 0,5 hektarlık örnek alanı analiz etmektedir. Bu çalışma ile Ağdaş'daki orman alanlarının yaklaşık 7.037 hektar veya toplam bölge alanının %6,9'u olduğu ve 2000 ile 2016 yılları arasında %1,3 oranında azaldığı değerlendirilmiştir. Buna karşılık, meralar yaklaşık %2,07 oranında artmıştır. Ağaç örtüsü yalnızca Ağdaş'ın %20,9'unda bulunmakta olup toplamda 21.296 hektarı kaplamaktadır. Ağaç örtüsünün %67'sinden fazlası orman dışındaki arazi kullanım kategorilerinde bulunurken, ağaçların yaklaşık %33'ü orman alanlarında bulunmaktadır. Ağaç örtüsü ile karşılaştırıldığında, çalı örtüsü Ağdaş'da benzer bir dağılıma sahiptir ve 24.220,43 hektar (%21) alan çalı örtüsü (%24) ile kaplıdır. Bunun aksine, tarım arazileri büyük bir çoğunluğu oluşturmakta ve 70.924,73 hektarlık (%70) bir alan tarım örtüsü ile kaplıdır. Çalışma, ayrıca, sel, yangın, orman emvali üretimi ve otlatma gibi tahribatları tespit etmeyi başarmış ve nehir erozyonu, yağmur yüzey akışı ve toprak kayması gibi olaylara ilişkin kanıtlar bulmuştur.

A Regional Land Use Assessment with Collect Earth: Case Study of Agdash, Azerbaijan

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Abstract

Periodic land use and land use change assessments (LULUCA) monitor the total extent and changes in land use categories over time for effective land use planning and management. Collect Earth is a free access software to monitor the land-use trends in land-use categories, namely, forestlands, croplands, grasslands, wetlands, settlements, and other lands, over time. The study reports the extent and changes of all land-use categories in Azerbaijan's Agdash region, analyzing 1,116 0.5-hectare sample plots using visual interpretation of very high spatial and temporal resolution satellite imagery on the Google Earth platform. Forestlands in Agdash were assessed to be approximately 7,037 ha or 6.9% of the total region area and have declined by 1.3% from 2000 to 2016. In contrast, grasslands have grown approximately by 2.07%. Tree cover only exists in 20.9% of Agdash, totaling 21,296 ha. While more than 67% of tree cover exists in non-forest land-use categories, almost 33% of trees are found in forestlands. Compared to tree cover, shrub cover has a similar distribution in Agdash, and 24,220.43 ha (21%) of land has shrub cover (24%). On the contrary, crop cover has a significant majority, and 70,924.73 ha of land area (70%) has crop cover. The study also succeeded in identifying disturbances like flooding, fire, logging, and grazing, and found evidence of river erosion types, rainfall surface runoff, and landslides in Agdash.

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INTRODUCTION

Periodic LULUCA monitor the total extent and changes in land use categories over time to generate highly accurate activity data (Maniatis et al. 2021). Besides, LULUCA contribute to evaluating the impacts of human activities on lands (Li and Shao 2014) and accordingly provide insights for policy development, decision-making, and land use planning and management (Romero-Sanchez and Ponce-Hernandez 2017, Khadka et al. 2020).

Open Foris Collect Earth (CE)[1] is free access remote sensing software for conducting LULUCA for a specific period through a systematic sample-based approach. Through structured and enhanced data gathering methods, operators gather activity data by visually interpreting moderate to very high geographic and temporal resolution images and statistics from Google Earth, Bing Maps, Yandex Maps, and Google Earth Engine (Makinta et al. 2015, Bey et al. 2016, Schepaschenko et al. 2019, Tzamtzis et al. 2019, Maniatis et al. 2021, Reytar et al. 2021).

Many scientific studies have used CE tool and Google Earth imagery for low-cost LULUCA at different spatial scales worldwide (Schepaschenko et al. 2015, Bastin et al. 2017, Martín-Ortega et al. 2017, Martín-Ortega et al. 2018, Koskinen et al. 2019, García-Montero et al. 2021a, 2021b, Ateşoğlu et al. 2023, Bassullu and Martín-Ortega 2023, Melo et al. 2023, Bassullu and Martín-Ortega 2024). Additionally, national, regional, or local-level remote sensing studies are available in Azerbaijan (Gambarova et al. 2010, Gambarova and Gambarov 2016, Gallaun et al. 2010, Hansen et al. 2013, Baumann et al. 2015, Bayramov et al. 2016, Asam et al. 2019, Bayramov et al. 2019, Abiyev et al. 2020, Buchner et al. 2020, Mammadov et al. 2021, Mamedaliyeva 2021, Narmin 2022, Bassullu and Sanchez-Paus Díaz 2023).

Forest inventory and forest management plans are outdated in Azerbaijan and date back to 1988. Although the Azerbaijani government intends to update the forest inventory and management plans, funding and human resource constraints now stand in the way of this progress. FAO-led "Forest Resources Assessment and Monitoring to Strengthen Forest Knowledge Framework in Azerbaijan" project provided additional funds through the Global Environment Facility (GEF) to update the forest inventory and management plans in Agdash region.

Although a national LULUCA is available in Azerbaijan through a CE study (Bassullu and Sanchez-Paus Díaz 2023), a regional initial assessment was needed with intensified grids in line with the objectives of the above-mentioned project. The primary purpose of the regional-level LULUCA was to furnish up-to-date data on land use and land use change trends, to pinpoint the locations of the forestlands in Agdash, and to offer a rough approximation of the forest extent to update the forest inventory and create new forest management plans. The study also aimed to detect erosion trends, disturbances, and the extent of tree, shrub, and crop cover in the region. Hence, an intensified regional grid was established over the region. The Collect Earth methodology provides a cost-effective and rapid LULUCA, contributing to updated forest inventory and newly developed forest management plans in Agdash.

MATERIAL AND METHOD

Material

Collect Earth software

CE is an easy-to-use, freely accessible program that gathers both historical and present land use and land use change data via the Google Earth platform. Users of Google Earth can identify the features of different landscapes. By creating user-generated sampling designs and data-collecting forms, CE can be readily tailored for particular data-gathering needs, objectives, and procedures. CE supports the following activities: LULUCA, land/forest inventories, land-use change matrix development, monitoring of all land-use categories, and consistent and accurate land representation. Many other studies mentioned the other benefits of using CE (Bey et al. 2016, Bastin et al. 2017, Bastin et al. 2019, Tzamtzis et al. 2019, Maniatis et al. 2021, Reytar et al. 2021, García-Montero et al. 2021b).

With CE, one can interpret freely accessible satellite imagery with a moderate to very high spatial and temporal resolution. This includes data from DigitalGlobe, SPOT, Sentinel-2, Landsat, MODIS, and Planet, as well as archives and databases in Google Earth, Bing Maps, Yandex, Google Earth Engine, and Google Earth Engine Code Editor (Bey et al. 2016, Maniatis et al. 2021). During the visual interpretation process, each sample plot's Normalized Difference Vegetation Index (NDVI) is automatically constructed using MODIS data collected between 2000 and the present, along with Landsat and Sentinel data for all available dates without cloud cover (Schepaschenko et al. 2019).

Operators can obtain information and data on different parameters by using data-collecting forms. Table 1 presents some of the parameter names.

[1] https://openforis.org/tools/collect-earth/

Table 1. The names of parameters in data collection forms

Parameter Name	Parameter Name
The most recent date of the image that is available	Infrastructure elements and cover
Vegetation type	The type and impact of disturbances
Tree and shrub cover	Erosion trends
The count of trees and shrubs	The type and year of land cover and land use category that is currently in place
The length of linear vegetation	The accuracy of the assessment
Other customized parameters for each sample plot	

Utilizing a Java and HTML-based data entry form, CE employs the Google Earth platform (Makinta et al. 2015). This study adjusted forms to fit Azerbaijan's unique classification schemes in accordance with IPCC Guidelines, Chapter 3 on Consistent Land Representation[2] (IPCC 2006), and the Food and Agriculture Organization of the United Nations (FAO) (FAO 2001).

The information entered in CE is automatically filled into a Saiku BI data mining tool and saved to the "Collect" database. With the help of the open-source browser-based Saiku BI software, CE users may visualize and analyze the data to execute quick, accurate, consistent, and economical assessments. Saiku BI arranges the gathered data, enables users to perform data analysis, and exports the results as tables or graphics in the following formats: XLS, CSV, PDF, PNG, and JPG (Makinta et al. 2015, CE 2024).

Very high-resolution imaging covers a large portion of Azerbaijan. Since more than 95% of the imagery utilized in the assessment was shot after 2009, clear and accurate interpretation is possible. Furthermore, land use and land use change analysis was supplemented by the availability of Sentinel-2, Landsat, and MODIS NDVI statistics.

In CE, the selection criteria are usually based on what is publicly available for the required dates and how cloud-free they are. No specific very high-resolution images for this research were purchased, so they were freely available on Google Earth for 2016. Most likely, it was Landsat for 2000. Thus, free satellite imagery in this research was employed to gather LULUCF data in representative plots between 2000 and 2016.

Location

The research focuses on the Agdash region in Azerbaijan (Figure 1). Situated beside the Kura River, the Agdash district spans 102,000 ha.

Figure 1. Map of Agdash, Azerbaijan

[2] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch03_Land%20Representation.pdf

METHODS

Systematic sampling design

First, CE methodology and survey were prepared. An area attributes file was created to determine the per-plot expansion parameters. Additionally, a plot file in CSV format was created that included details about each plot’s ID number, coordinates, elevation, slope, aspect, climate, soil, and district. Then, a systematically intensified 1 x 1 km grid of 1,116 sampling units in Agdash was established to generate past and present activity data (Figure 2). The research used the shapefiles provided by the Ministry of Ecology and Natural Resources (MENR) to create the sampling grids. Each sample plot in the assessment represents an area (also known as a plot expansion factor) equivalent to 0.91 km^2 in Agdash, calculated by dividing the region area by the number of sample plots.

Figure 2. Systematic sampling design

Spatial sampling plot

A set of 0.5 ha (70 m x 70 m) square sample plots was established based on the forest definition of FAO (FAO, 2001). Each sample plot consists of an internal grid of 49 sampling units, encompassing around 2% of the 0.5 ha sample plot (Figure 3).

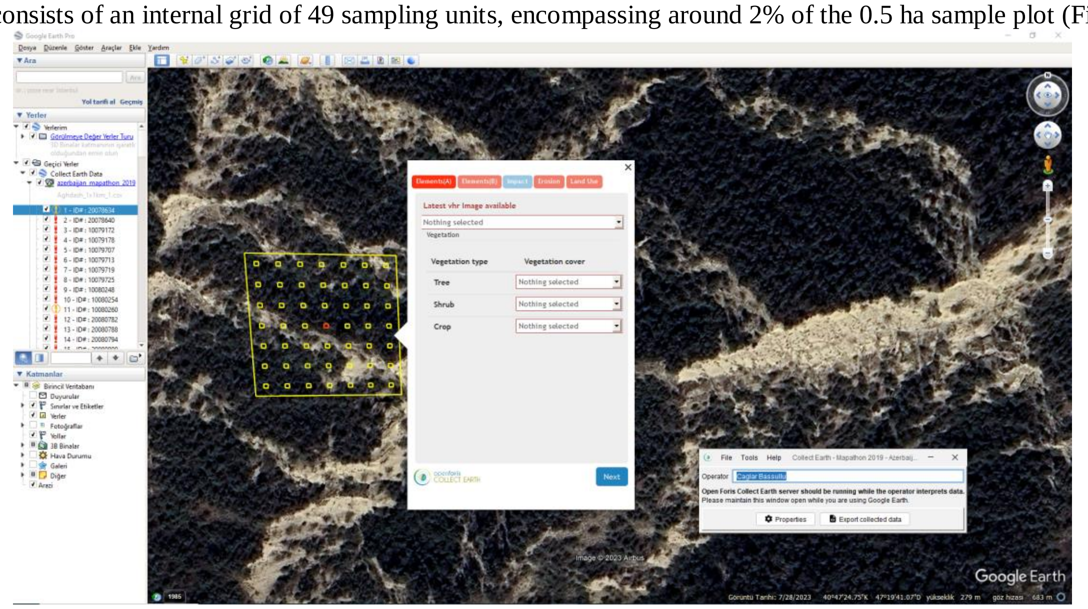

Figure 3. An illustration of a spatial 0.5 ha sample plot

The origin of the reference data

Data collection forms were created using Open Foris Collect[3] to collect information through sample units (Figure 4). The operator can view the data-collecting forms and sample plots created by the CE program using Google Earth Pro and scripts that can be found in Google Earth Engine Code Editor. The scripts facilitate the operator’s ability to analyze land use trends and comprehend different vegetation types.

[3] https://openforis.org/tools/collect/

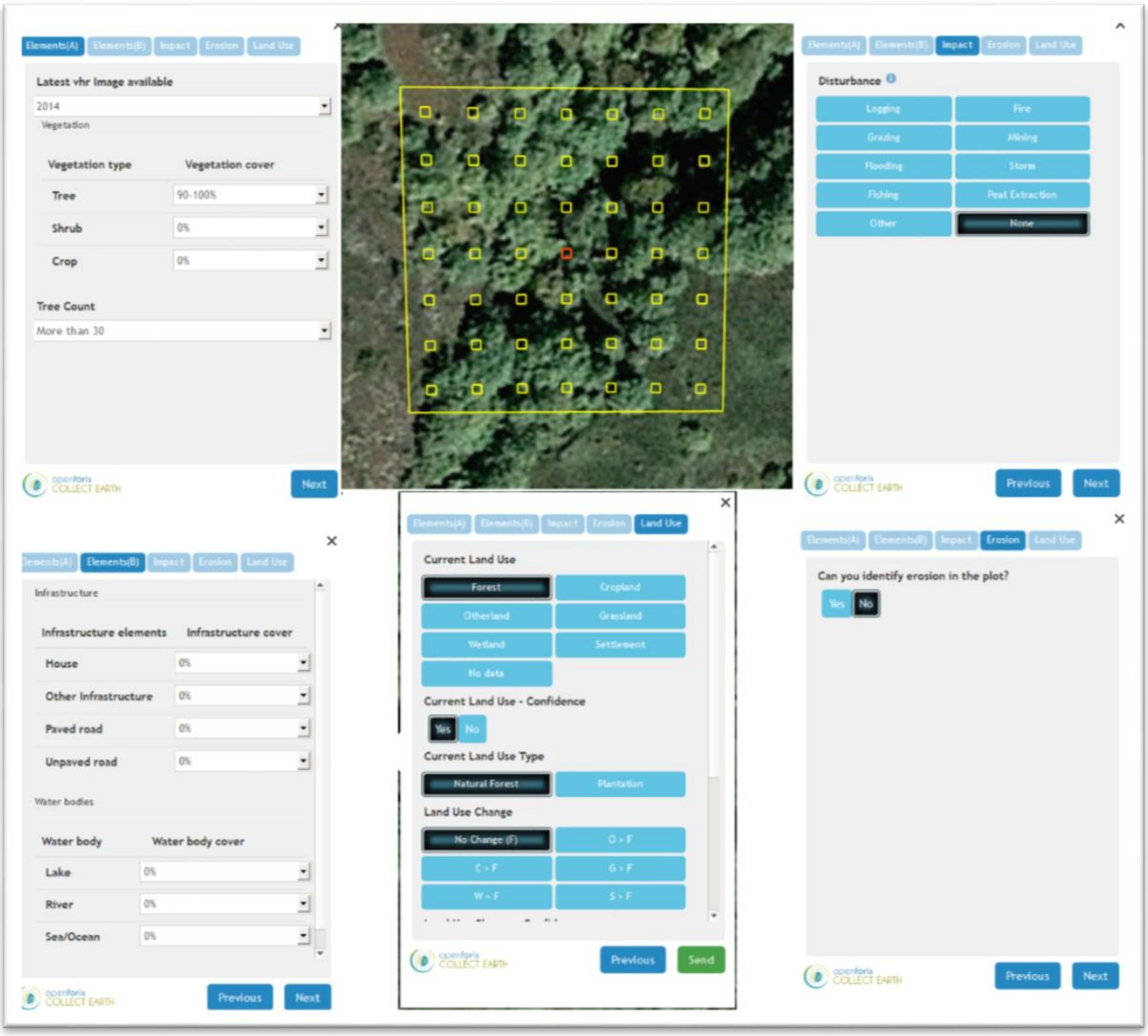

Figure 4. An illustration of a data collection form

Reference labeling protocol

The LULUCA was conducted by collecting the data from all land-use categories namely, forestlands, croplands, grasslands, wetlands, settlements, and other lands, recommended in the Good Practice Guidance for Land Use and Land Use Change and Forestry (LULUCF) (IPCC 2003) and 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories - Volume 4 Agriculture Forestry and Other Land Use (IPCC 2006). Moreover, the study used the land use types and sub-classes under these main categories specified for Azerbaijan. Furthermore, the study assigned each sampling unit to one of the six main land-use categories, specific land-use types, and sub-classes of Agdash (Table 2).

Table 2. Land use classification

Land Use	Land Use Type	Sub-classification
Forestland	Natural forest	
	Plantation	
Grassland	Shrubland	With trees
		Without trees
	Grassland	Grassland
		With trees
		With shrubs
		With trees & shrubs
		Sown pasture
Cropland	Non-irrigated rainfed cropland	
	Irrigated crops	

	Orchard
	Cropland perennial
	Greenhouse
Settlements	Village
	Urban
	Infrastructure
	Mine
	Built up
Wetlands	Season lake
	Sea/Coast
	Saline, brackish, or alkaline
	Other
Other Lands	Rock or stone
	Sand
	Dune
	Unknown

Martínez and Mollicone (2012) defined the hierarchical rules to classify land-use categories. The hierarchical principles consider the FAO forest definition and concentrate on a particular percentage. For instance, a sample plot with 20% tree cover is considered forestland unless it comprises more than 20% of crops or infrastructures. Once the LULUCA determines the land-use category, it also determines land-use types and sub-classes employing the categorization scheme presented in Table 2.

Data gathering, quality assurance, and Saiku analysis

Using very high-resolution image repositories and optical datasets that are freely available on Google Earth, Bing Maps, Google Earth Engine Explorer, and Code Editor (i.e., Annual Greenest-Pixel, 32-Day, and 8-Day Top of Atmosphere Reflectance Composites from Landsat 7 and 8) as a visual assessment exercise, the study carried out the sampling design for both historical and current LULUCA. Additionally, utilizing bands 4, 5, and 3 from Landsat 7 images and bands 5, 6, and 4 from Landsat 8 images, Google Earth Engine made it possible to visualize false color composites.

The assessment gathered data for all land use categories and saved the information into a comprehensive database. A follow-up data collection was carried out for missing plots to conclude the assessment of missing sample plots and finalize LULUCA. Followingly, a review process for all sample plots and an analysis procedure were conducted in 2019 and 2020. Overall, 1,116 sample plots were evaluated.

For the reporting period, every accessible very high-resolution satellite image (Earth, Bing, Yandex, Here, etc.) was evaluated for each sample plot. Multiple public satellite imagery is available for every plot, preventing discrepancies, simplifying the process of interpretation, and tracking changes in land use over time. Furthermore, by characterizing the variation in visible and near-infrared reflectance of vegetation cover, the research was able to identify the land-use category using the MODIS NDVI data, Sentinel-2, Landsat 7/8, and Google Earth Engine plot imagery.

The research employed a semi-automated data-cleaning process to identify potentially inconsistent plots in 2019 and 2020. Then a data quality control process was performed for all sample plots to improve data quality. These plots were also corrected by hand. The study reevaluated 194 plots (17.4%) that had low confidence, poor precision, inadequate marking, or inconsistent plots. A further quality control was performed in all forest plots. Lastly, using data analysis performed with the bespoke Saiku BI software—which was embedded into the CE installation file—the LULUCA was carried out in 2019 and 2020, taking uncertainty estimations into account.

RESULT AND DISCUSSION

Results

Land use and land use change in Agdash

Agdash has minimal land use changes in its forestlands, croplands, and grasslands out of the six land use classifications. In contrast, no change has been observed in otherlands, wetlands, and settlements (Table 3).

Table 3. Land use summary in Agdash

	Initial area in 2000 (ha)	Current area in 2016 (ha)	Change in area (ha)	Change in area (%)
Forestland	7,129.03	7,037.63	-91.40	-1.28
Cropland	67,543.01	67,268.82	-274.19	-0.41
Otherland	1,462.37	1,462.37	0.00	0.00
Grassland	17,639.79	18,005.38	365.59	2.07
Wetland	1,279.57	1,279.57	0.00	0.00
Settlement	6,946.24	6,946.24	0.00	0.00
Total	102,000.00	102,000.00	0.00	

Forestlands show a very minor decline of 1.28% over the assessed timeframe, transitioning to grasslands, which indicates an increase of approximately 2.07%. Like forestlands, croplands also declined since 2000 by 0.41%. The lands converted from croplands to grasslands were 365.59 ha; on the contrary, lands converted from grasslands to croplands were 91.40 ha. The net change between these land-use categories over eighteen years is 274.19 ha. Grasslands have increased to 18%, and the share of otherlands has decreased to 1% (Figure 5).

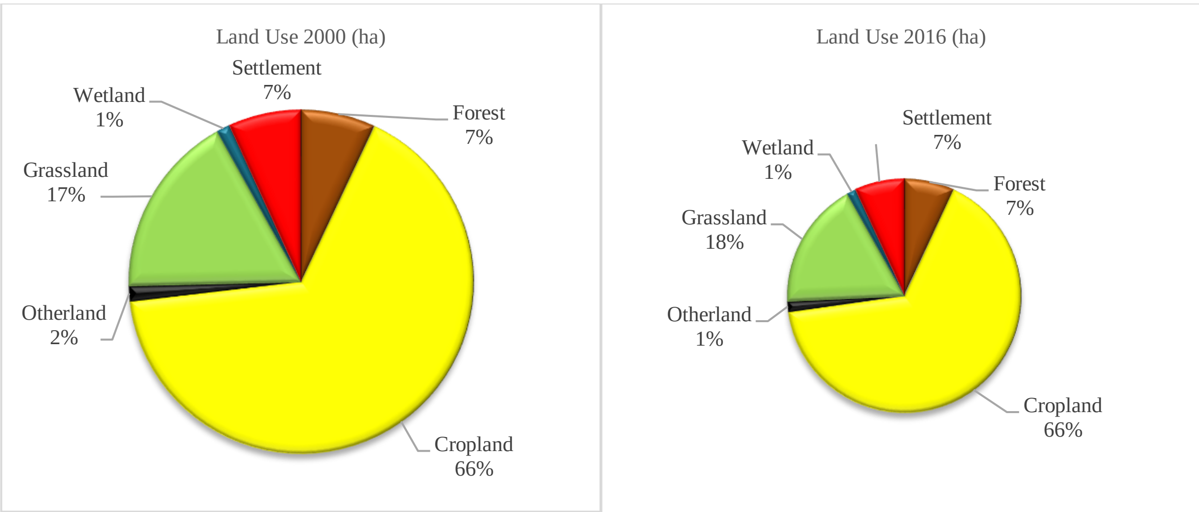

Figure 5. Land use distribution charts

An analysis of the patterns across all land-use categories from 2000 to 2016 was made possible by the land-use change matrix (Table 4). In 2000, there were 7,129 ha of forestlands altogether; however, up until 2016, 91.40 ha of forestlands were converted to grasslands.

Table 4. Land use change matrix in Agdash

	Land Use 2016 (ha)						
Land Use 2000	**Forestland**	**Cropland**	**Otherland**	**Grassland**	**Wetland**	**Settlement**	**Total**
Forestland	7,037.63						7,037.63
Cropland		67,177.42		91.40			67,268.82
Otherland			1,462.37				1,462.37
Grassland	91.40	365.59		17,548.39			18,005.38
Wetland					1,279.57		1,279.57
Settlement						6,946.24	6,946.24
Total	7,129.03	67,543.01	1,462.37	17,639.79	1,279.57	6,946.24	102,000.00

The land-use change matrix shows that there is little long-term change in the area of land-use categories. It should be emphasized that no forest land was turned into towns for urbanization or croplands for agriculture. The findings demonstrate that, as a result of forestry techniques, Agdash has minimal forest loss and zero conversion to crops or settlements. A field-based land use change assessment should be conducted to obtain more accurate results.

Disturbance trends in Agdash

Utilizing satellite images from the past to the present, the study succeeded in identifying disturbances like flooding, fire, logging, and grazing. For instance, NDVI graphics identified a fire disturbance since they provided the operator with information on the date of the fire in the sample plot. Based on the opinions of the experts—some of whom are aware of the issues with overgrazing in the area—the study also identified grazing disturbance. According to Table 5, fire disturbance affects all land-use categories in Agdash to varying degrees. Croplands have experienced 69% of the disturbance compared to other land-use categories. In croplands, fire poses the most severe threat among disturbances (94%). However, using fires as a management tool to burn plant residues following harvest could be effective in croplands.

Table 5. Disturbance trends (ha)

Land Use 2016	Logging	Fire	Grazing	Flooding	Other	None	Total
Forestland		822.58				6,215.05	822.58
Cropland	91.40	11,698.92			91.40	55,387.10	11790.32
Otherland		91.40				1,370.97	91.40
Grassland	456.99	2,559.14	365.59			14,623.66	3381.72
Wetland		182.80		91.40		1,005.38	274.19
Settlement		731.18				6,215.05	731.18
Total	548.39	16,086.02	365.59	91.40	91.40	84,817.20	17,091.40

Additionally, 822.58 ha of forestlands—nearly 12% of the entire forest area—were damaged by fire. Other concerning risks to grasslands are fire, overgrazing, and logging; these must be balanced for the sustainability of those regions (Figure 6).

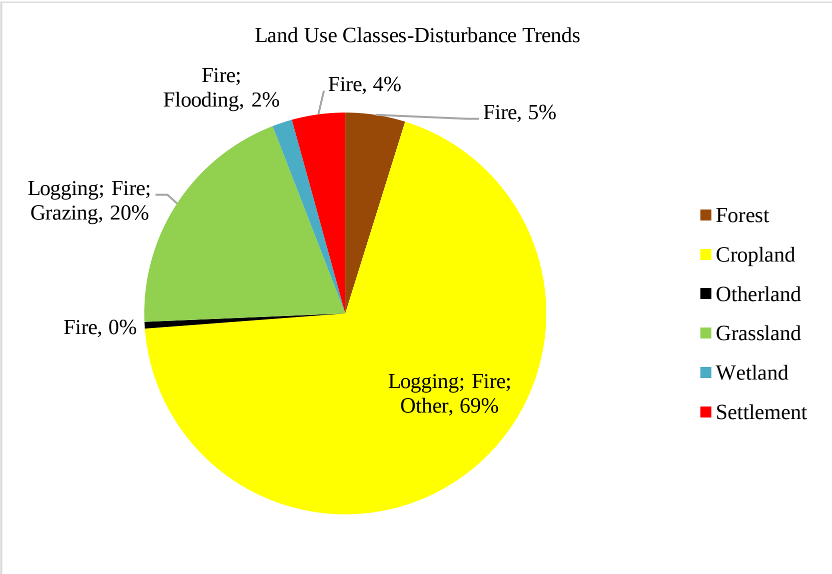

Figure 6. Disturbance trends

Erosion trends in Agdash

Agdash is prone to different levels of erosion. The research found evidence of river erosion types, rainfall surface runoff, and landslides. The total area prone to erosion is 731.18 ha. Erosion mainly occurs in open forestlands (38%) and wetlands (25%). Croplands, otherlands, and grasslands have a 13% share with a low to high-level erosion trend (Table 6). No erosion trend is seen in settlements. However, a field survey is required to detect sedimentation loss.

Table 6. Erosion trends (ha)

Land Use 2016	Type	Very low	Low	Medium	High	Very High	Total	%
Forestland	Rainfall Surface Runoff	91.40	91.40	91.40			274.19	0.38
Cropland	River Erosion			91.40			91.40	0.13
Otherland	Rainfall Surface Runoff			91.40			91.40	0.13

Grassland	Landslide				91.40		91.40	0.13
Wetland	River Erosion		91.40			91.40	182.80	0.25
Total		91.40	182.80	274.19	91.40	91.40	731.18	

Trends in tree, shrub, and crop cover in Agdash

The total area of Agdash is 102,000 ha. Of all the land, just 20.88%—or 21,295.7 ha—have tree cover—a substantial amount of tree cover represented by forestlands. Compared to tree cover, shrub cover has a similar distribution in Agdash, and 24,220.43 ha (21%) of land has shrub cover (24%). On the contrary, crop cover has a significant majority, and 70,924.73 ha of land area (70%) has crop cover. Over 61% of this area has 90-100% crop cover (Table 7).

Table 7. Trends in tree, shrub, and crop cover (ha)

	Tree Cover	Shrub Cover	Crop Cover
0%	80,704.30	77,779.57	31,075.27
2%	1,005.38	1,279.57	365.59
4%	1,462.37	2,102.15	548.39
6%	1,279.57	2,193.55	182.80
8%	1,370.97	3,381.72	548.39
10-19%	4,387.10	5,575.27	1,827.96
20-29%	2,376.34	2,102.15	913.98
30-39%	2,284.95	2,102.15	913.98
40-49%	1,279.57	1,462.37	1,005.38
50-59%	1,279.57	731.18	1,645.16
60-69%	1,005.38	1,096.77	2,741.94
70-79%	1,096.77	639.78	4,935.48
80-89%	1,096.77	548.39	11,881.72
90-100%	1,370.97	1,005.38	43,413.98
Total	102,000.00	102,000.00	102,000.00

Tree cover distribution in Agdash

Trees are found in all land-use categories. Table 8 shows the tree cover across several land use categories.

Table 8. The distribution of tree cover (ha)

Tree Cover	Forestland	Cropland	Otherland	Grassland	Wetland	Settlement	Total
0%	91.40	60,322.58	1,188.17	15,537.63	913.98	2,650.54	80,704.30
2%		822.58		91.40		91.40	1,005.38
4%	91.40	913.98		274.19	91.40	91.40	1,462.37
6%		639.78		456.99	91.40	91.40	1,279.57
8%		456.99	274.19	274.19	91.40	274.19	1,370.97
10-19%	456.99	1,462.37		1,096.77		1,370.97	4,387.10
20-29%	548.39	548.39		182.80	91.40	1,005.38	2,376.34
30-39%	1,370.97	456.99				456.99	2,284.95
40-49%	639.78	456.99				182.80	1,279.57
50-59%	731.18	274.19				274.19	1,279.57
60-69%	548.39	182.80		91.40		182.80	1,005.38
70-79%	1,005.38					91.40	1,096.77
80-89%	822.58	91.40				182.80	1,096.77
90-100%	731.18	639.78					1,370.97
Total	7,037.63	67,268.82	1,462.37	18,005.38	1,279.57	6,946.24	102,000.00

Tree cover in forestlands occupies 6,946.24 ha out of 21,295.7 ha (32.6%). 91.4 ha of forestland does not have tree cover, which might be explained by recent harvesting operations or the early regeneration phase. 67.4% of tree cover exists in other land-use categories rather than forestlands. The majority of this area is represented in croplands (6,946.24 ha) and settlements (4,295.7 ha). Compared to croplands and settlements, tree presence in grasslands is relatively low and represents 2,467.74 ha.
Tree presence can also be identified in other words (Figure 7). Trees cover 6,946.24 ha in croplands, equaling 10% of croplands. Grasslands have similar characteristics in that trees cover 14% of the grassland area. On the other hand, settlements contain trees that cover 62% of the total area. Finally, 19% of otherlands and 29% of wetlands contain trees.

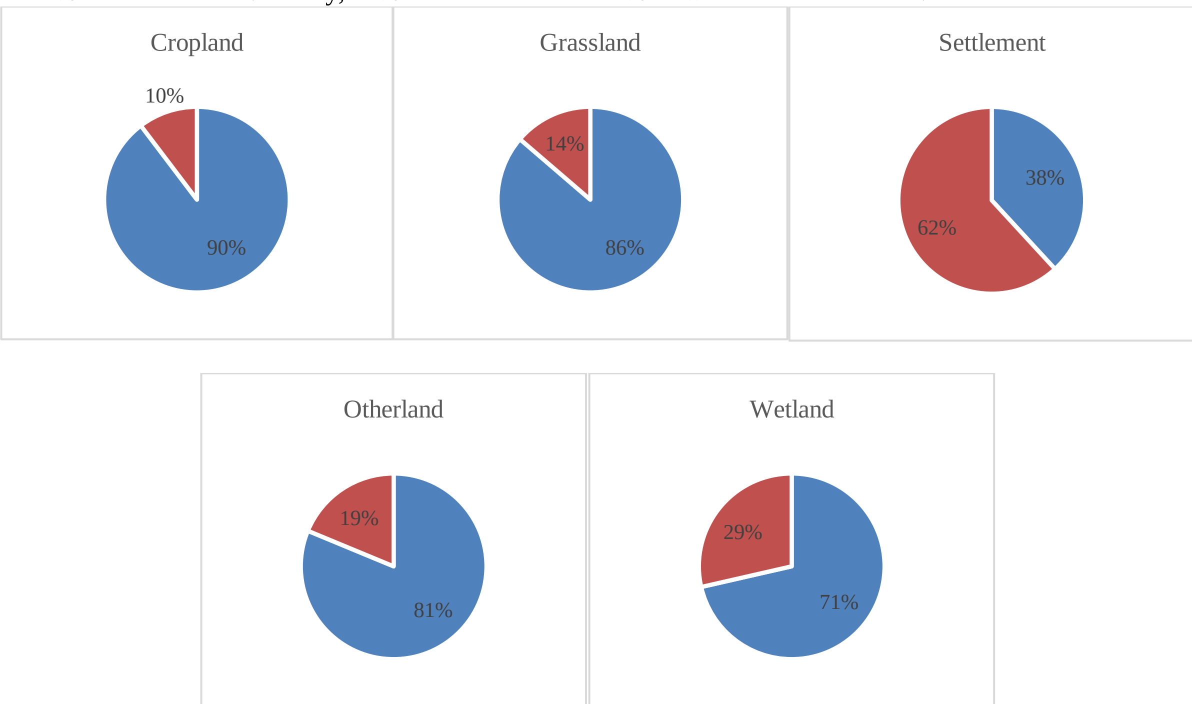

Figure 7. Tree presence outside forests

Vegetation cover trends in Agdash

The distribution of the area with vegetation cover (tree-shrub-crop) changes based on the land-use categories. Trees and shrubs can be seen in all land-use categories. Forestlands do not have crop cover. Trees cover 6,946.24 ha in forestlands. Shrubs can be seen in forestlands and cover 1,553.76 ha. 10.32% and 15.63% of croplands have trees and shrubs, respectively. 18.75% and 25% of otherlands are covered by trees and shrubs, respectively. 13.7% and 54.31% of grasslands are covered by trees and shrubs, respectively. 28.57% and 21.43% of wetlands are covered by trees and shrubs, respectively. 61.84% and 25% of settlements are covered by trees and shrubs, respectively (Table 9). In summary, 32.6% of trees are in forestlands, and 67.4% are in other land-use categories.

Shrub cover trends in Agdash

The total area with shrubs was estimated to be 24,220.43 ha in Agdash (Table 10). The distribution of shrubs by percentage is relatively heterogeneous in different land-use categories. In total, 14,532.26 ha (60%) of land with shrubs have a shrub percentage between 2-19%. Only 9,688.17 ha of land with shrubs have shrub cover over 20% with a decreasing area according to different shrub cover percentages. Shrubs are mainly in croplands (10,510.75 ha) and grasslands (9,779.57 ha). Forestlands contain shrubs in 1,553.76 ha. The study used the diameter of the tree crown or the crown shadows to distinguish between shrubs and trees. To differentiate shrubs from trees, a 3 m threshold was applied.

Table 9. Vegetation cover (ha)

	Forestland			Cropland			Otherland			Grassland			Wetland			Settlement		
Vegetation cover	Tree	Shrub	Crop	Tree	Shrub	Crop	Tree	Shrub	Crop	Tree	Shrub	Crop	Tree	Shrub	Crop	Tree	Shrub	Crop
0%	91.40	5,483.87	7,037.63	60,322.58	56,758.06		1,188.17	1,096.77	1,462.37	15,537.63	8,225.81	16,086.02	913.98	1,005.38	1,096.77	2,650.54	5,209.68	5,392.47
2%		91.40		822.58	731.18					91.40	365.59	365.59		91.40		91.40		
4%	91.40			913.98	1,096.77					274.19	548.39	365.59	91.40	91.40		91.40	365.59	182.80
6%		91.40		639.78	1,370.97	91.40		91.40		456.99	456.99	91.40	91.40			91.40	182.80	
8%		182.80		456.99	2,193.55	91.40	274.19	182.80		274.19	456.99	182.80	91.40		91.40	274.19	365.59	182.80
10-19%	456.99	274.19		1,462.37	2,924.73	182.80		91.40		1,096.77	1,370.97	913.98		91.40	91.40	1,370.97	822.58	639.78
20-29%	548.39	365.59		548.39	913.98	731.18				182.80	822.58		91.40			1,005.38		182.80
30-39%	1,370.97	456.99		456.99	822.58	822.58					822.58					456.99		91.40
40-49%	639.78	91.40		456.99	365.59	913.98					1,005.38					182.80		91.40
50-59%	731.18			274.19	91.40	1,645.16					639.78					274.19		
60-69%	548.39			182.80		2,559.14				91.40	1,096.77					182.80		182.80
70-79%	1,005.38					4,935.48					639.78					91.40		
80-89%	822.58			91.40		11,881.72					548.39					182.80		
90-100%	731.18			639.78		43,413.98					1,005.38							
Total	7,037.63	7,037.63	7,037.63	67,268.82	67,268.82	67,268.82	1,462.37	1,462.37	1,462.37	18,005.38	18,005.38	18,005.38	1,279.57	1,279.57	1,279.57	6,946.24	6,946.24	6,946.24

Table 10. Shrub cover (ha)

Land Use Current	2%	4%	6%	8%	10-19%	20-29%	30-39%	40-49%	50-59%	60-69%	70-79%	80-89%	90-100%	Total
Forestland	91.40		91.40	182.80	274.19	365.59	456.99	91.40						1,553.76
Cropland	731.18	1,096.77	1,370.97	2,193.55	2,924.73	913.98	822.58	365.59	91.40					10,510.75
Otherland			91.40	182.80	91.40									365.59
Grassland	365.59	548.39	456.99	456.99	1,370.97	822.58	822.58	1,005.38	639.78	1,096.77	639.78	548.39	1,005.38	9,779.57
Wetland	91.40	91.40			91.40									274.19
Settlement		365.59	182.80	365.59	822.58									1,736.56
Total	1,279.57	2,102.15	2,193.55	3,381.72	5,575.27	2,102.15	2,102.15	1,462.37	731.18	1,096.77	639.78	548.39	1,005.38	24,220.43

Sampling uncertainties in Agdash

The study obtained the standard error (ha) of an area estimate from the IPCC (2006). The following equation calculates the standard error of an area estimate:

$$A\sqrt{(p_i * (1 - p_i))/(n - 1)} \quad (1)$$

Where p_i is the proportion of sampling units in the particular land-use category i, A is the known total area, and n is the total number of sample plots. The 95% confidence interval for Ai, the estimated area of land-use category i, will be given approximately ±2 times the standard error (Tables 11 and 12).

Table 11. Uncertainty estimates for Agdash in 2000

Land Use 2000	Sample Size	Area (ha)	Confidence Intervals (ha)	Uncertainty %
Forestland	78	7,129	± 1,526.5	± 21.41%
Cropland	739	67,543	± 2,831.7	± 4.19%
Grassland	193	17,640	± 2,264.3	± 12.84%
Otherland	16	1,462	± 711.7	± 48.67%
Wetland	14	1,280	± 666.4	± 52.08%
Settlement	76	6,946	± 1,508.3	± 21.71%

The overall uncertainty for land use in the baseline year is 26.82%. The research does not include field validation.

Table 12. Uncertainty estimates for Agdash in 2016

Land Use 2016	Sample Size	Area	Confidence Intervals (ha)	Uncertainty %
Forestland	77	7,038	± 1,517.4	± 21.56%
Cropland	736	67,269	± 2,837.2	± 4.22%
Grassland	197	18,005	± 2,282.7	± 12.68%
Otherland	16	1,462	± 711.7	± 48.67%
Wetland	14	1,280	± 666.4	± 52.08%
Settlement	76	6,946	± 1,508.3	± 21.71%

The overall uncertainty for land use in the target year is 26.82%. The research does not include field validation.

The possibility that Agdash's forest area has not changed actually can be inferred from the uncertainty analysis, given the range of the forest area changes between 2000 and 2016 is within the confidence interval. Stated differently, there is no discernible change taking place in Agdash since the "change" in the forest area is less than the confidence interval.

In order to better understand land use changes, a specific land use change assessment would need to employ a different methodology, such as building a change layer through the application of automatic change detection and then sampling using CE. Besides, the remote sensing studies should be supported by field validation.

DISCUSSION

The use of free access very high-resolution imagery has updated the land use and land use change statistics in Agdash to conduct forest inventory in the field and develop new forest management plans where available data and plans are outdated. The LULUCA carried out with CE illustrates the usefulness of the program for land use and land use change monitoring, which is essential for generating activity data for forest inventory and forest management plans.

The current forest extent and land use change from 2000 to 2016 were evaluated by analyzing the regional data collection findings based on predefined factors of interest (land use, land use change, disturbance, erosion, tree-shrub-crop cover, etc.). Using CE, the study remotely examined 1,116 sampling units distributed over a regional grid. According to the findings, Agdash has forestlands covering 7,037 ha.

The results revealed that Agdash has experienced relatively minor land use changes. While forestlands have decreased by 1.3% in Agdash (91.4 ha), grasslands have grown by approximately 2.07% in Agdash. No increase has been observed in settlements in the region.

In conclusion, studies conducted globally, nationally, and locally verify that there aren't many variations in land use between Azerbaijan's land-use categories (Hansen et al. 2013, Baumann et al. 2015, Bayramov et al. 2016, Asam et al. 2019, Abiyev et al. 2020, Buchner et al. 2020, Mamedaliyeva 2021, Narmin 2022, Bassullu and Sanchez-Paus Díaz 2023). According to Hansen et al. (2013), Azerbaijan lost 8,686 hectares of forest between 2000 and 2018. The land use change in Nagorno-Karabakh between 1987 and 2010 was examined by Baumann et al. (2015), who found a 4.9% shift in that area. Between 1987 and 2000, the percentage of forest area transferred to other land uses was limited to 0.2%, and between 2000 and 2010, it was 0.01%. On the other hand, they reported that settlements and croplands were converted to other land-use categories. Using object-based categorization of the Landsat-8 time series, Bayramov et al. (2016) conducted a quantitative assessment of changes in land cover in Azerbaijan over the course of 2014 and 2015. The extent, changes in land use, and degradation of grasslands were mapped by Asam et al. (2019). The dynamics of the forest cover in Samur-Yalama National Park were examined by Abiyev et al. (2020). Using the topographic correction of multi-temporal Landsat composites, Buchner et al. (2020) assessed the change in land cover in the Caucasus Mountains from 1987. Mamedaliyeva (2021) examined long-term data on the state of the forest cover in the Khachmaz district. Through monitoring the forest landscapes of the Shamakhi district, Narmin (2022) discovered a reduction of 65 ha of tree cover between 2001 and 2020. Finally, estimations of Azerbaijan's forest extent were published by Bassullu and Sanchez-Paus Díaz (2023). They showed that in 2016, forest cover covered 1,301,188 ha, or 15.1% of the total land, and tree cover covered 2,751,167 ha or 31.9% of the land.

Tree cover only exists in 20.9% of Agdash, totaling 21,296 ha. More than 67% of tree cover exists in non-forest land-use categories in Agdash.

Tree cover exists in settlements (88%), wetlands (29%), otherlands (19%), grasslands (14%), and croplands (10%) in Agdash. With a few minor variations, García-Montero (2015) and García-Montero et al. (2021b) also present comparable data for trees in croplands, grasslands, and settlements.

The study detected disturbances during the LULUCA. As noted by Hansen et al. (2013), for the whole of Azerbaijan, fires affect land-use categories at various levels in Agdash. Apart from fires, the erosion-prone area was 731.18 ha in Agdash, leading to land and forest degradation. Systematically planned afforestation and vegetation activities in otherlands, regulated grassland management in grasslands, forest restoration in forestlands, and watershed management in wetlands would increase the number of trees and other vegetation and lower the risk of erosion.

The study demonstrated that CE is a time- and money-effective program for producing land use and land use change data at the regional level, especially in areas where prior information on this kind of spatial data is either lacking or out-of-date.

The land use and land use change data developed in this study provides up-to-date activity data to support the forest inventory process and the development of new forest management plans in Agdash. Further steps will be refining the sample plots to select locations for onsite data collection for forest inventory. Field-based forest/land inventory could validate the results of this research and support the renewal of forest management plans in Agdash.

Due to the variability of the region's landscapes, uncertainty analyses regarding land use change are statistically insignificant; hence, a more focused ground-based LULUCA is advised to quantify the forest area and land use changes more accurately.

CONCLUSION

The main objective of the regional LULUCA was to achieve the objectives of the "GCP/AZE/007/GFF" project by supplying up-to-date data on land use and trends in land use change, identifying the locations of forestlands, updating the forest inventory and preparing forest management plans in Agdash region. The study also aimed to detect erosion trends, disturbances, and the extent of tree, shrub, and crop cover in the region.

The LULUCA indicated that forestlands in Agdash cover 7,037 ha. The estimate updated the forestry statistics and revealed that forests have declined by 1.3% in Agdash since 2000. Trees cover 20.9% of Agdash, totaling 21,296 ha.

Previously unreported tree cover that was not spotted using coarser resolution data has been found through CE's access to very high-resolution images and the human aspect of field knowledge from the operators.

The research results demonstrated the value of collaboration in producing quantifiable and validated spatial activity data in the LULUCF sector across intricate and diverse environments by fusing local expertise with freely accessible, open-source CE software. However, a specific field inventory on land use and land use change would have to be carried out to obtain significant statistics. Besides, the field inventory could compare, validate, or integrate the results/datasets of this study for improved LULUCA by using other remote sensing technologies and field inventory techniques. The LULUCA will help improve the final field inventory design of the forests and the Agdash regions' forest management plans.

COMPLIANCE WITH ETHICAL STANDARDS

Authors' Contributions

CB: Designed and delivered capacity-building training, collected data, and coordinated the data collection by other operators through Collect Earth, conducted the quality control, data cleansing procedure, and reassessment of inconsistent sampling units, and performed the statistical analyses. CB conceived, designed, and wrote the paper. CB edited the manuscript. CB revised and read the manuscript, and approved the submitted version.

Conflict of Interest

The author declares that there is no conflict of interest.

Statement on the Welfare of Animals

This study does not involve animals.

Statement of Human Rights

This study does not involve human participants.

Disclaimer

The designations employed and the presentation of information in this article do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal or development status of any country, territory, city, or area or its authorities or concerning the delimitation of its frontiers or boundaries.

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