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RESEARCH ARTICLE

Structural Change in Agricultural Land Use Intensity across Farm Sizes in Pakistan

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ABSTRACT

This study investigates structural changes in agricultural land-use intensity (LUI) in Pakistan and differences across small, medium, and large farms and provinces. Data were obtained from the Pakistan Economic Survey and Agricultural Censuses of 2010 and 2024, conducted by the Pakistan Bureau of Statistics (PBS). Annual land-use data cover 2010–11 to 2024–25 (provisional), while food-grain production data extend to 2025–26 (provisional). National LUI, measured as a percentage of total culturable area, remained statistically stable, ranging from 72.54% to 73.68% (mean: 73.17%; 95% CI: 72.95–73.38), with no significant annual trend (0.016 percentage points; $p = 0.51$). In contrast, cropping extent increased significantly by 0.39 percentage points annually. Census comparisons show higher LUI on small and medium farms than on large farms in both years. However, large-farm LUI increased substantially, from 62.5% in 2010 to 84.3% in 2024. In 2024, count-weighted LUI estimates were 98.4%, 95.7%, and 91.2% for small, medium, and large farms, respectively. Despite rising food-grain production, from 34.302 million tonnes in 2010–11 to 48.742 million tonnes in 2025–26, its association with annual LUI ($r = 0.18$) and aggregate yield ($r = 0.11$) was insignificant. Findings suggest output expansion primarily reflected increased cultivated area rather than productivity gains. Policy priorities include irrigation improvements, farm-size-responsive support, and harmonised land-use statistics.

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1. INTRODUCTION

Land use intensity (LUI) is the degree of land usage, compared to its potential. It is a multi-dimensional concept and can be evaluated by land use, management practices or inputs/outputs (Erb et al., 2013; Roilo et al., 2024). Agriculture is a significant sector in Pakistan; agricultural value added 23.4pc of the total GDP whereas 33.1pc of the population is involved in agriculture pursuits, according to Pakistan Economic Survey 2025-26. Therefore, sustaining crop production, increasing productivity and good land and water management are at the heart of food security (GoP, 2026).

Over the past few decades, agricultural land intensification has emerged as an important land cover change, possibly manifesting itself in changes to agricultural productivity, agricultural input use and the frequency of agricultural use. Intensification can boost production from a given area of irrigated land, better quality seeds or varieties, higher crop fertility, crop protection and quality land and water use, but can also affect soil, water, and ecosystem functions (Matson et al., 1997; Erb et al., 2013). Current research also indicates that there is no single indicator to measure all aspects of agricultural intensity since the intensity of use depends on the indicator chosen and the scale on which it is assessed (Roilo et al., 2024).

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The agricultural production and potential of farmland can be heavily impacted by urban expansion on farmland and changes in agricultural land use intensity (Jiang et al., 2012; Jiang et al., 2013). Previous research in Pakistan has identified agricultural land use change that occurred in the urbanizing city of Hyderabad (Peerzado et al., 2019), and other urban areas (Saqib et al., 2024). Moreover, some studies conducted in the Gilgit-Baltistan territory have also reported changes in size of agricultural lands in certain districts in GBA and expansion of urban development areas (Ali et al., 2022). Understanding the processes is vital for elaborating policies to balance urbanization with implementation of the protection and sustainable use of agricultural land.

Increased food demand has been addressed partly by intensification of agriculture even in the face of limited areas of land use. The change of labor, capital, technology & management may impact on the intensity of land utilization, and the change of land area may impact on the total production, while the change of the same land area and frequency of cultivation may impact on the intensity of land utilization and total production (Chen & Li, 2009; Long & Zou, 2010). Hence, it is important to understand the difference between intensity of land use and total cropped area or cropping intensity; two different aspects of land use.

Agriculture has been in existence for thousands of years, and has adapted to multiple environments, societies and technologies. In modern agriculture agricultural management practice has been improved or make better use of the land, a better use of the land utilizes improved seeds, improved machines, better irrigation, better fertilizer practice and better crop protection. But increased production is no guarantee of more sustainable land use. Intensified production can go together with increased output, but can also put strain on the soil, water and other natural resources unless they are managed properly (Matson et al., 1997; Erb et al., 2013).

From a global level agriculture continues to be influenced by food production, water resources, environmental degradation etc. The potential for production will likely continue to be constrained by climate variability and water stress/land degradation, while there will likely be a greater demand for agricultural products in the future driven by population growth and dietary shifts. The negative impacts of environmental degradation and land-cover change on agriculture productivity has been extensively studied in Pakistan in the recent years highlighting the importance of water availability, seeds quality and other input variables of agriculture (Fatima et al., 2024; Jadoon et al., 2025; Iqbal et al., 2026).

The use of technology is also a determinant in food production, especially in developing nations. However, the effect of farm size on productivity is still undecided. Some studies have suggested that the use of land is more intensive in small farms as the farmers apply more family labor, but others have shown that it depends on the type of crop, location, and opportunity cost of family labor (Sial et al., 2012). Previous studies on Pakistan had cautioned that linkages between apparent size of farms and productivity could be "artificial" and could even be U-shaped (see Mahmood and Haque, 1981). The equitable distribution of land is also relevant and is important as it relates to food security and the economic status of household/farm heads (Naseer et al., 2016; Riaz et al., 2026).

In this context there are two gaps in the evidence for Pakistan. For the first time, to our knowledge, few studies examine the scale of the culturable land use by farms of different sizes; most farm-size studies focus on output per acre or yields. Secondly, in the few studies that have been conducted to compare census rounds, such studies do not always specify whether the indicators themselves are defined in the same way in both rounds and not, which could lead to a mistakenly perceived change in structure if a change in definition occurs. Land use intensity (the proportion of cultivable land under cultivation), cropping intensity (occurrence of cultivation on cultivated land within a year) and productivity (output per unit of area cultivated) are the three parameters strongly related which need to be distinguished because of the constrained nature of working places on farms and the necessity of spreading out cultivation. That same definition needs to be used year after year and farm size after farm size as well.

There are three points on which this study is unique or useful. Firstly, it calculates LUI using one-area-based formula for the 2010 and 2024 Agricultural Censuses, by province and by farm-size group, enabling a 'like-for-like' comparison. Second, it continues to break this area-based measure from the farm-level averages released by PBS for 2024 and explicitly explains the weights used in calculating the farm averages. Thirdly, it connects the annual national LUI series and the food-grain production with the derived aggregate yield on tests that have the short sample constraint and the constraint that allow for autocorrelation without mixing LUI with cropping intensity and productivity. Specific objectives are listed below.

Objectives

1. To explore the intensity of land use in small, medium and large farms in the provinces of Pakistan based on 2010 and 2024 Agricultural Census.

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2. To estimate the trend in national land use intensity; and to statistically investigate the association pattern between land use intensity and aggregate yield of food-grain production.
3. To make policy implications.

2. MATERIALS AND METHODS

The data include descriptions and the farm-size classification and procedures for analysis. There is no primary data gathered and the study is based on official secondary data and published census data.

Data Description

Annual land-use data (cultivated area, culturable waste, total cropped area and cropping intensity) for 2010-11 to 2024-25 were taken from Table 2.2 of the Pakistan Economic Survey 2025-26 (GoP, 2026). The areas under food-grain crops, food-grain output, and the yield of food-grain crops came from Tables 2.3 and 2.4 of the same Survey, with the yield of food-grain crops (Table 2.5) being from the same Survey. There is no LUI value for 2025-26 because the table of land-use of the Survey and the PBS reports did not have one for 2025-26, and therefore, food-grain production is described in this year but not used in the correlation tests. The Agricultural Census 2010 (PBS, 2012) and Agricultural Census 2024 (PBS, 2026) are the sources of farm-level data. Data for Rabi 2023-24 is for the annual Census (2024) and data for Kharif 2024 is also provisional.

There was a need for attention being paid to two aspects of the annual series. The land-utilization rows of 2018-19 and provisional 2024-25 are the same, while the land-utilization row of 2017-18 is the same as 2016-17. We treat these repeated rows as non-independent observations and remove them from all of the inferential tests, leaving only 13 annual observations (2010-11 to 2017-18 and 2019-20 to 2023-24). They are listed in Table 1 for completeness. Two Agricultural Censuses, conducted in 2010 and 2024, are used as two benchmarks, rather than as an annual series.

Extract and merge data. The amount of land under cultivation and culturable waste was determined from the area figures for each province and farm size class and were obtained in each census from Table 1 of the census report. The size classes were then sorted into the three generalized size classes as described in Section 2.2, and the areas were added together and the ratio then calculated, and so when calculating the LUI for a group it is a ratio of total area and not a mean ratio. Both censuses were carried out using the same formula. Islamabad Capital Territory is only included in the 2024 provincial comparison as it does not appear in the 2010 provincial comparison.

Farm Sizes

Extract and merge data. The amount of land under cultivation and culturable waste was determined from the area figures for each province and farm size class and were obtained in each census from Table 1 of the census report. The size classes were then sorted into the three generalized size classes as described in Section 2.2, and the areas were added together and the ratio then calculated, and so when calculating the LUI for a group it is a ratio of total area and not a mean ratio. Both censuses were carried out using the same formula. Islamabad Capital Territory is only included in the 2024 provincial comparison as it does not appear in the 2010 provincial comparison.

Analytical Measures

The analysis consisted of three parts: (i) descriptive summaries of the annual land-use series, (ii) comparing the land-use situations by farm size and province on the basis of census data, and (iii) statistical tests of the trend and of the relationship between LUI and food-grain production and yield. Census indicators perform statistics on an annual basis. Food-grain production is used here as an indicator of agricultural output and food-grain aggregate would indicate agricultural productivity.

Descriptive Statistics

Data were summarized by descriptive statistics (mean, standard deviation, range, percentage change, tables and graphs). The mean and 95% CI (based on the t distribution; n = 13) are reported for the LUI series each year. Estimated linear trend using ordinary Least Squares (OLS), slope shown with 95% confidence interval. Ensuring a good result is that the OLS residuals are free from serial correlation; because of this, the Durbin–Watson statistic (dL = 1.01 and dU = 1.34 for n = 13) and the lag-1 autocorrelation coefficient were checked for the set of annual series. Robustness checks of this trend were performed using Newey–West heteroskedasticity and autocorrelation consistent (HAC) (Newey & West, 1987; lags 1 and 2) standard errors, the Cochrane–Orcutt procedure, and with the non-parametric Mann–Kendall test and Sen's slope (Mann, 1945; Kendall, 1975).

A correlation position study was conducted between derived aggregate yield and LUI, and between food-grain production and LUI using Pearson correlation coefficient. Fisher z transformation (Fisher, 1915) was used to obtain confidence intervals for r values; and a Spearman rank correlation was calculated to check results. The correlations

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have been repeated after series have been linearly determined and on the differences between successive years in order to eliminate chance correlation between two time series (Yule, 1926). Effective samples sizes for both series, adjusted for the lag-1 autocorrelation of both series, were also computed. For a test at the 5% level, with 13 observations, the Fisher z approximation of statistical power (Cohen, 1988) calls for a correlation of 0.71 absolute or greater. The common-period sample covers 2010-11 to 2023-24 without 2018-19. The provisional 2024-25 row is not included as it is repeated from 2023-24 and there is no LUI value for 2025-26 production. All calculations were done in Python (NumPy and SciPy).

The census tables used here are published totals, after which no standard errors were given, and confidence intervals were only reported for the annual series.

Land Use Intensity

Intensity of land use (LUI) is equal to the percentage of land in a country which is used in agricultural production activities. Total culturable area includes the cultivated area plus cultured waste which comprises the land area that might have been cultivated but was not cultivated in the reference period or the previous year (GoP, 2026). Each farm-size group includes each area column from the PBS Agricultural Census in the same manner as they were included in the previous census for comparison. The annual survey series and estimates from the census are not a continuous time series and there are differences in statistical coverage.

$$\text{LUI} = [\text{Total Cultivated Area} / (\text{Total Cultivated Area} + \text{Culturable Waste})] \times 100$$

Why this indicator. One of the reasons for using area-based LUI is it is an indicator of the amount of available cultivable land that is cultivated. It is different to the intensity of cropping and to productivity. Cropping intensity (CI) is defined as total cropped area / net area sown x 100; and it reveals the frequency of cropping of specific land over a year and may be higher than 100 percent. LUI is capped at a maximum of 100 percent and remains the same for a farmer if he is growing two crops (or more) on a plot instead of one. Productivity is measured as output per unit area, in this case, food grains in tonnes per hectare. The same can be said for a high LUI coupled with a low yield or a low LUI coupled with a high yield. In this way the three are kept separate so that an increase in production does not get translated as an increase in the use of land (Erb et al., 2013; Roilo et al., 2024). The indicator has some limitations: it provides no information on input utilization, nor on the quality of input management practices, and it is based on definitions and measurement of culturable wastes.

Aggregate food-grain yield is derived by the authors and is not a series of the official PBS, it equals the total food-grain output divided by the total food-grain area. Average LUI is reported for the 2024 Census at the farm level per size class and per province in Tables 5.1 and 5.2. Estimated farm numbers of weighted averages were generated first, and area-weighted averages were generated second that were published as class averages. For group g for which classes have been published, LUIcount(g) is the farm-weighted average equal to $\Sigma\, nk \times LUIk / \Sigma\, nk$, in which nk is the estimated number of the farms, and Ak is acreage and LUIk is the PBS class average, and LUIarea(g) is the acre-weighted average equal to $\Sigma\, Ak \times LUIk / \Sigma\, Ak$, in which Ak is acreage and LUIk is the PBS class average. These averages at the farm level are separated from the area-based averages (called the area-based LUI) of the 2010 and 2024 censuses, as they are both based on different levels of aggregation and cannot be compared directly.

Relationship of the two censuses. Neither census of 2010 nor 2024 was a census on a pre-decided form. The Census 2024 has been called by PBS as an Integrated Digital Count with a reference period of Rabi 2023-24 and Kharif 2024 and the design of Census 2010 presented in the report is different from the 2024 Census, in addition differences are also present in the estimation procedure between the two types of censuses. The wide concept of boundaries of farms and the definition of a holding differ from one time period to another, as do the geographic coverage (for instance Islamabad under urban areas in 2010) and the treatment for fallow land and culturable waste, having impact on area totals and hence LUI. The differences cannot be checked by use of the published tables. This is because the census comparison is interpreted as compared to two benchmarks, and not as a completely harmonized assessment of change, and that larger changes are to be interpreted with this proviso (Section 4).

Conceptual Framework of Research

The study process is simple in nature. Official data are gathered, indicators are calculated using the definitions listed above, the data are checked for internal consistency, and the results are accounted to the objectives. Figure 1 shows this process.

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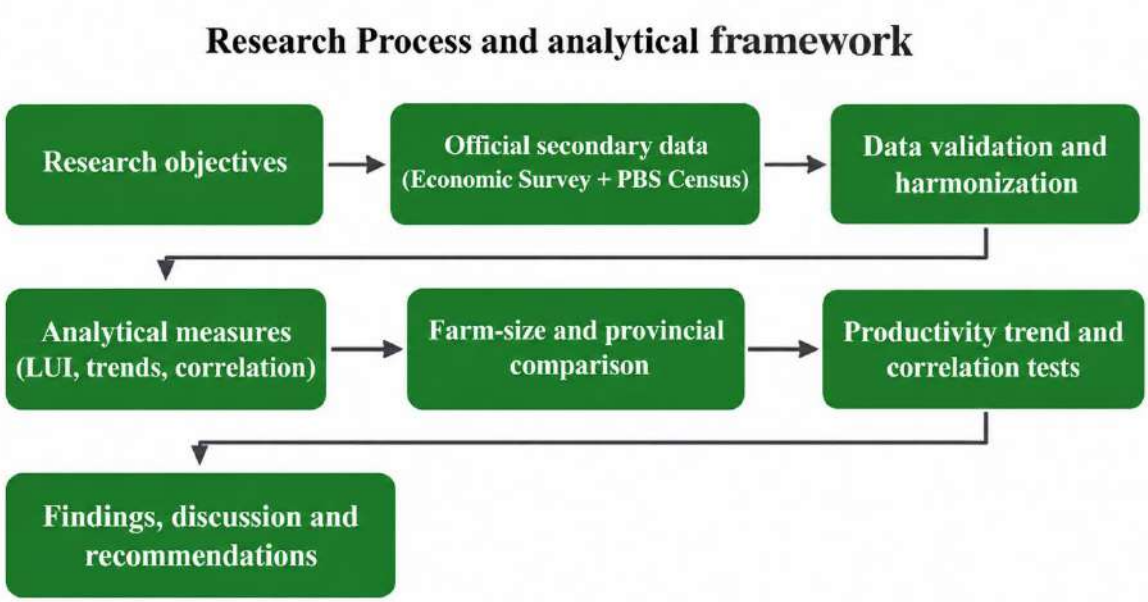

Figure 1. Conceptual framework

3. RESULTS

In this chapter, the land use intensity across the time and small, medium and large farms has been reported in the provinces of Pakistan and their relationship with food-grain production and yield has been discussed.

Land Use Intensity across Different Periods

Table 1 gives the annual land-use data for 2010-11 to 2024-25. The rows for 2018-19 and 2024-25 repeat the preceding year and are excluded from the statistical tests.

Table 1. Land use intensity and land-utilization indicators in Pakistan, 2010-11 to 2024-25

Fiscal year	Cultivated area (mha)	Culturable waste (mha)	Total culturable area (mha)	LUI (%)	Total cropped area (mha)	Cropping intensity (%)
2010-11	22.03	7.98	30.01	73.41	22.72	145.2
2011-12	22.03	8.19	30.22	72.90	22.50	150.2
2012-13	22.26	8.21	30.47	73.06	22.56	148.2
2013-14	22.06	8.27	30.33	72.73	23.16	150.4
2014-15	23.24	8.30	31.54	73.68	23.26	150.5
2015-16	22.74	8.27	31.01	73.33	24.04	153.9
2016-17	22.11	8.37	30.48	72.54	23.01	147.6
2017-18	22.15	8.29	30.44	72.77	23.45	149.0
2018-19	22.15	8.29	30.44	72.77	23.45	149.0
2019-20	22.80	8.20	31.00	73.55	24.10	153.1
2020-21	22.50	8.10	30.60	73.53	23.83	152.8
2021-22	22.56	8.22	30.78	73.29	23.98	152.9
2022-23	22.17	8.16	30.33	73.10	24.22	151.9
2023-24	22.52	8.21	30.73	73.28	24.59	152.2
2024-25 (P)	22.52	8.21	30.73	73.28	24.59	152.2

Source: GoP (2026), LUI calculated by the authors from the published cultivated-area and culturable-waste columns. The rows for 2018-19 and 2024-25 (P) repeat the preceding year.

National LUI was stable over the period (Table 1). Across the 13 non-repeated observations it ranged from 72.54 to 73.68 %, with a mean of 73.17 % (SD = 0.35; 95% CI 72.95–73.38). The linear trend was small and not significant (slope = 0.016 percentage points per year, 95% CI −0.037 to 0.069, p = 0.51; Table 5). This was unchanged when autocorrelation was allowed: Durban Watson statistic = 1.97, lag-1 residual autocorrelation = −0.03 and results of the Newey–West, Cochrane–Orcutt and Mann–Kendall tests were each statistically insignificant with values of p =

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0.31, p = 0.29, and p = 0.95 respectively. This was not the case with cropping intensity. It rose from 145.2 to 152.2 percent, with a significant trend of 0.39 percentage points per year (95% CI 0.09 to 0.68, p = 0.015; Figure 2), and total cropped area increased by 0.14 million hectares per year (p < 0.001). There was no significant trend in cultivated area and culturable waste. The cropped land base remained virtually the same, so all the increased area of cropped land was due to increased use of the same land.

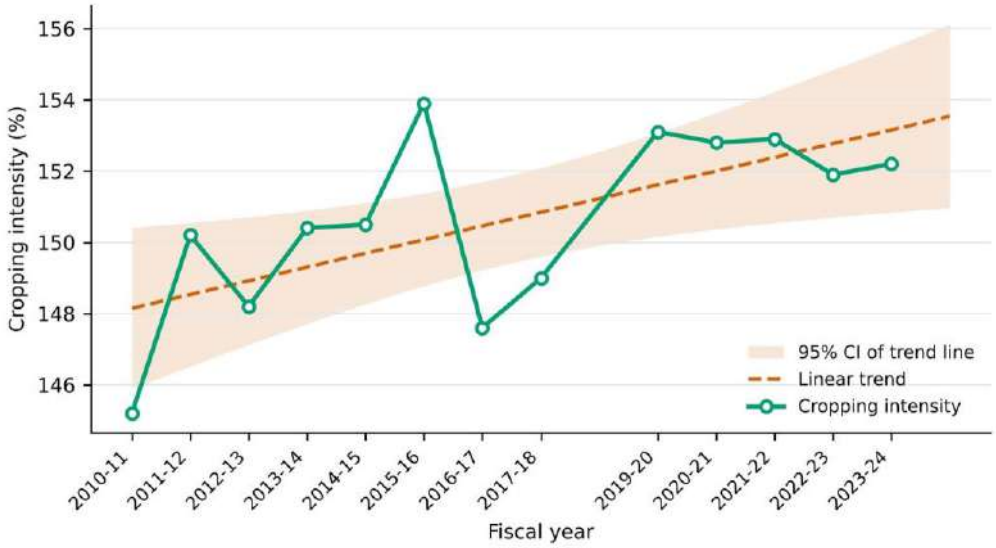

Figure 2. Cropping intensity in Pakistan, 2010-11 to 2023-24, with the fitted linear trend and its 95% confidence band (2018-19 omitted because it repeats 2017-18)

Source: Authors' calculations based on GoP (2026)

The same area-based formula is used for the like-for-like comparison in Table 2. National LUI increased by 0.5 percentage points for small farms and 0.2 percentage points for medium farms but at about 22 percentage points for large farms (62.5 to 84.3 percent) between the two censuses. In both years, small and medium farms had high LUI (well above nationally) while the main difference was the continuing decrease in the gap between the LUI of large farms and the other farms. The gains among farmers working on large farms in Balochistan (+32.3 points) and Punjab (+13.1 points) were the highest while modest in KP (+3.4 points) and Sindh (+3.4 points). LUI of medium farms in KP experienced a slight decline (89.3 to 87.8 percent). Census comparison is a descriptive one, while differences in the definitions of items, coverage and estimation between the two censuses (Section 2.3.2) might remain to be the factors that influence comparability.

Table 2. Comparable area-based land use intensity by farm-size group and province, Agricultural Censuses 2010 and 2024 (%)

Province	Small 2010	Small 2024	Medium 2010	Medium 2024	Large 2010	Large 2024
Khyber Pakhtunkhwa	92.5	92.6	89.3	87.8	68.8	72.2
Punjab	96.9	98.4	96.1	97.2	83.1	96.2
Sindh	93.1	97.0	83.8	92.0	70.6	74.0
Balochistan	82.2	86.0	79.7	82.9	32.2	64.5
Islamabad Capital Territory	—	92.6	—	95.9	—	89.6
Pakistan	95.1	95.6	92.2	92.4	62.5	84.3

Source: PBS (2012), Agricultural Census 2010, PBS (2026), Agricultural Census 2024, authors' calculations using the same area-based formula for both censuses. Islamabad Capital Territory was not included in the 2010 provincial comparison.

The trends in Figure 3 are also consistent in terms of the composition of the cultivated and culturable waste areas, which amounted to approximately 73 and 27 percent respectively of total culturable area respectively in all years.

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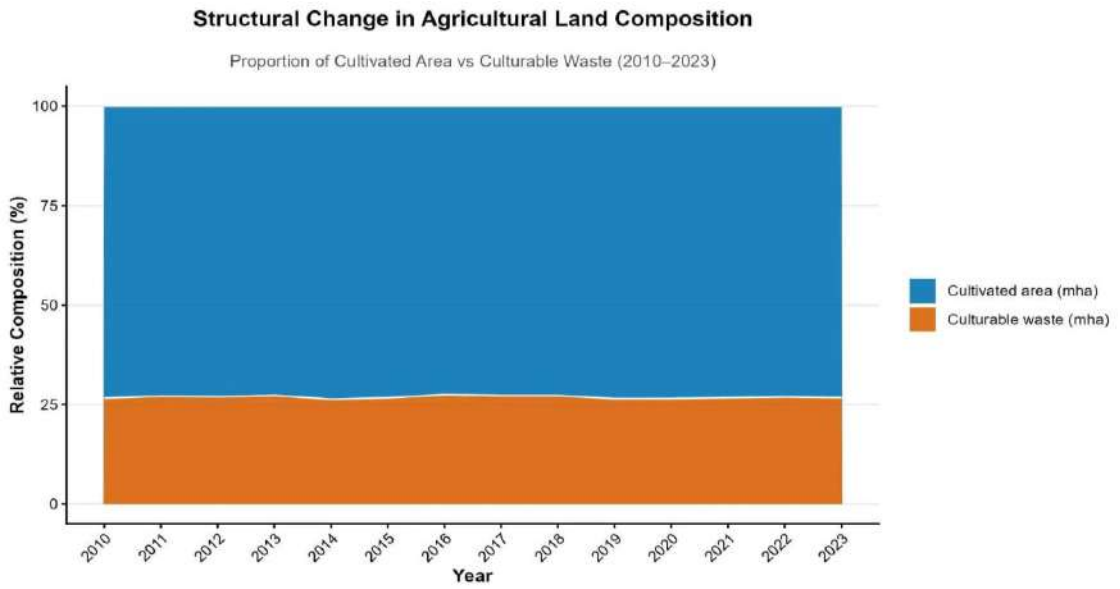

Figure 3. Structural change in agricultural land composition: cultivated area and culturable waste, 2010-2023

Source: Authors' calculations based on GoP (2026)

All-farm average LUI at farm level is 95 percent in Pakistan, 98 percent in Punjab, 94 percent in KP, 92 percent in Sindh, 89 percent in Balochistan and 93 percent in Islamabad Capital Territory (ICT) reported by PBS (2026, Table 5.1). The published size class averages to arrive at these headline numbers were combined in two ways to place them in context with the class-level values. An average of 95.3 was calculated by weighting by cultivated area, in agreement with the figure given by the PBS headlines. The two averages (area weighted and farm count weighted) are entirely distinct and should be used separately. The area weighted average weights have a larger number for larger size categories of farms thus having a land-area view. The farm count weighted average gives more weight to larger classes of farms and serves as an average of the farms. These measures may be different because the distribution of cultivated land by farm-size classes differs from that of farms. This is not to say that the two averages produced are interchangeable estimates, however, and they are reported separately for this reason Because the highest LUI is in the small volume of farms. The area-weighted value indicates the intensity of the average hectare while the farm-count-weighted value indicates the intensity of the average farm to each question. Table 3 and the group values of 98.4, 95.7 and 91.2 percent for small, medium and large farms are farm-count-weighted. They reflect the same ordering by farm size as the area-based estimates in Table 2, but rather than being based on area they are another farm-indicator based on class averages rounded to whole numbers and should not be compared directly with Table 2 or used to measure change from 2010.

Table 3. Farm-count-weighted average land use intensity by farm-size group, Agricultural Census 2024 (%)

Province	Small (<5 acres)	Medium (5-<25 acres)	Large (25+ acres)
Khyber Pakhtunkhwa	97.1	91.8	81.1
Punjab	99.0	97.8	96.9
Sindh	98.7	94.6	86.4
Balochistan	97.6	91.2	76.8
Islamabad Capital Territory	98.1	96.2	90.2
Pakistan	98.4	95.7	91.2

Source: Authors' calculations from PBS (2026), Each broad-group value is weighted by the estimated number of farms in the underlying size classes. These farm-count-weighted averages are a separate farm-level indicator and are not directly comparable with the area-ratio estimates in Table 2.

Land Use Intensity and Agricultural Productivity Trends

The trends of food-grain production and in an aggregate yield indicator, based on food-grain production, are compared with the trends of land use intensity. The concepts of production and productivity are separated all along.

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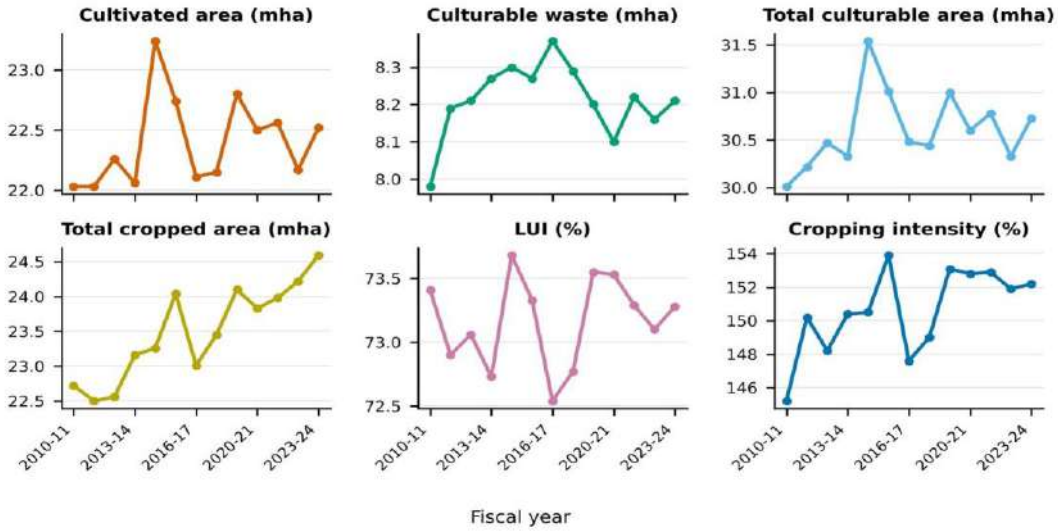
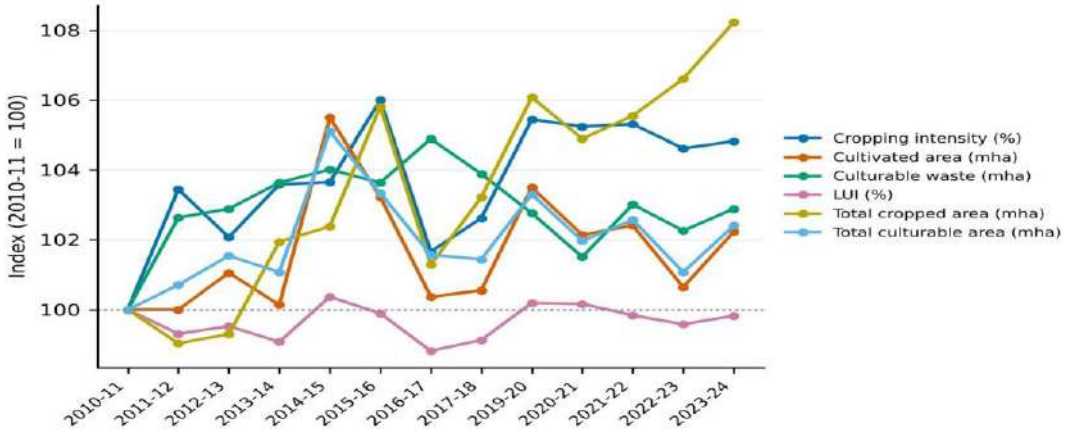


(A) Land use intensity indicators in their original units



(B) Relative change in land use intensity indicators (2010-11 = 100)

Figure 4. Land use intensity indicators in Pakistan, 2010-11 to 2023-24 (2018-19 omitted because it repeats 2017-18): (A) indicators in their original units, each on its own axis, and (B) relative change (2010-11 = 100)

Source: Authors' calculations based on GoP (2026)

The indicators of land use are presented in units in panel A of figure 4 and as indexes (2010-11 = 100) in panel B. Because the indicators are measured in different units (million hectares, wide and percent) they cannot sensibly be stacked on one axis or be drawn on one axis, as is done in Panel A. Panel B presents the six on a comparative basis relative to each other. Total cropped area in 2023-24 stood 8.2 percent higher than 2010-11; the cultivated area was 2.2 percent greater while culturable waste saw a substantial increase of 2.9 percent in 2023-24 as compared to 2010-11. Continuously averaged between 98.8 – 100.4 of its base level.

Correlation of Studied Variables

The standardized temporal heatmap is presented in Figure 5 and the correlation matrix of the land-use variables is presented in Figure 5 (n = 13). Each variable is represented as a z score, which compares them with their own mean and standard deviation to allow variables measured in different units to be compared; red cells are years above the mean of the variable and blue cells are years below the variable mean. Cropping intensity and total cropped area is low and high in the early and late years, respectively, while LUI is around the average without any trend. Using the data from the table, the Pearson correlation coefficients are provided in Panel B. The correlation of cultivated areas with total culturable area is very strong (r = 0.97) and strong with LUI (r = 0.76). The correlation of culturable waste with LUI is negative, r = −0.46. The total cropped area is tightly linked to the cropping intensity (r = 0.78), while LUI is moderately related to the cropping intensity (r = 0.40). Some of these variables are arithmetic components of each other (e.g. LUI is calculated from cultivated area and culturable waste) and the series are short, thus the coefficients are descriptive and do not suggest causal relations. A coefficient larger than 0.55 in absolute value is statistically significant at the 5% level of confidence for n = 13.

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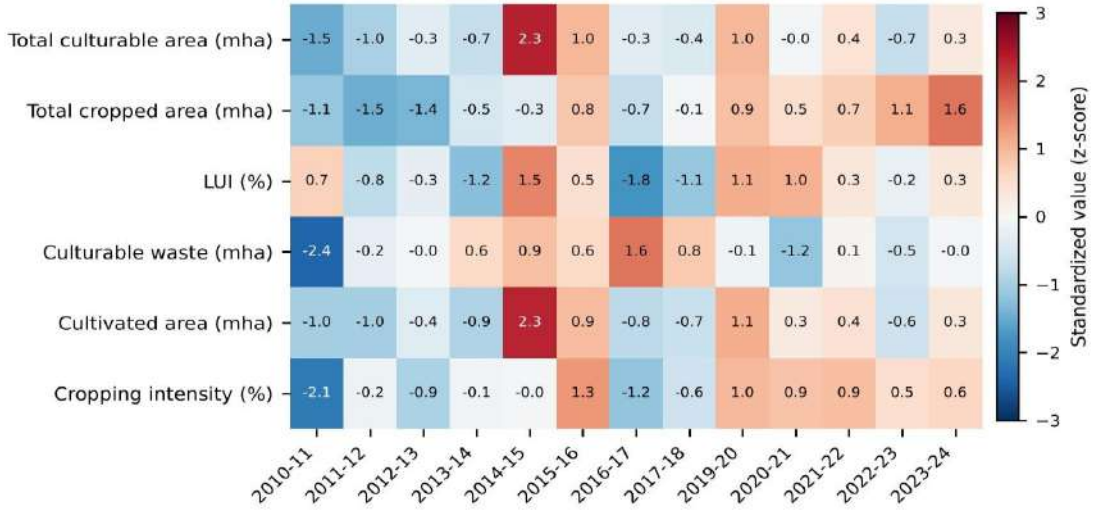
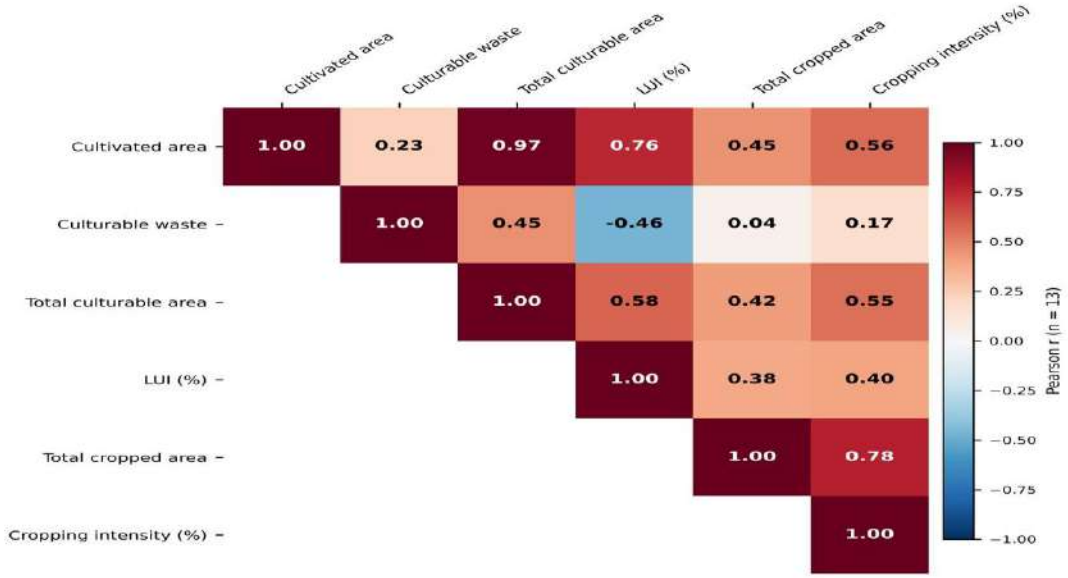


(A) Standardized temporal heatmap of land use intensity variables (z-scores)



(B) Correlation matrix of land use variables (n = 13)

Figure 5. Standardized temporal heatmap and correlation matrix of land use intensity variables in Pakistan, 2010-11 to 2023-24 (2018-19 omitted because it repeats 2017-18): (A) z-scores of each variable and (B) Pearson correlation matrix

Source: Authors' calculations based on GoP (2026)

The area, production and derived aggregate yield of foodgrains is given in Table 4. Food-grain production rose from 34.302 million tonnes in 2010-11 to 48.742 million tonnes in 2025-26 (P), an increase of 14.440 million tonnes (42.1 percent). The food-grain area grew from 13.094 to 15.153 million hectares, which is an increase of 15.7 percent. Aggregate yield of food grain increased from 2.62 to 3.22 tonnes per hectare, representing an increase of 22.8 percent over the same time. Logarithmically, about 42 percent of the increase in production can be attributed to area and 58 percent to yield. The area of foodgrains also increased as a proportion of the total cropped area from 57.6 per cent in 2010-11 to 62.4 per cent in 2023-24, with only minimal changes in the area of crops and LUI. Increase in production, that is, does not show that LUI caused the increase.

Table 5 is a summary of the tests. With the repeated 2018-19 row excluded (n = 13), the correlation between LUI and food-grain production was weak and not significant (r = 0.18, 95% CI −0.41 to 0.66, p = 0.56), and so was the correlation between LUI and derived aggregate yield (r = 0.11, 95% CI −0.47 to 0.63, p = 0.71). The same results were obtained using Spearman rank correlations (ρ = 0.05 and −0.01). Both production and yield are increasing ($p<0.001$), and so, the correlations between the levels of production and yield may be due to common trends; the

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Durbin–Watson statistics were 1.44 and 1.20, respectively, with the second one in the inconclusive range. The coefficients stayed non-significant after linear detrending (production: r = −0.04, p = 0.90; yield: r = −0.25, p = 0.41) and after first-differencing consecutive years (n = 11; production: r = −0.24, p = 0.48; yield: r = −0.51, p = 0.11). The effective sample size for each pair, adjusted for serial correlation, was 12.6, which is very close to the sample size that would be found if there were no serial correlation (LUI lag-1 coefficient 0.02). The power of these tests is low: correlations of 0.71 or more would be detected with 80% power with 13 observations, and r = 0.5 would be detected with about 41% power with 13 observations. The results that are not significant should thus be interpreted as "no evidence, not evidence of no evidence.

Table 4. Food-grain area, production and derived aggregate yield, 2010-11 to 2025-26

Fiscal year	Food-grain area (000 ha)	Food-grain production (000 tonnes)	Derived aggregate yield (tonnes/ha)
2010-11	13,094	34,302	2.62
2011-12	13,052	34,478	2.64
2012-13	12,761	34,468	2.70
2013-14	13,900	38,208	2.75
2014-15	13,962	37,498	2.69
2015-16	13,980	38,227	2.73
2016-17	13,830	40,168	2.90
2017-18	13,751	38,975	2.83
2018-19	13,616	38,931	2.86
2019-20	14,013	41,097	2.93
2020-21	14,439	45,228	3.13
2021-22	14,509	45,385	3.13
2022-23	14,069	46,817	3.33
2023-24	15,337	51,788	3.38
2024-25	14,879	47,491	3.19
2025-26 (P)	15,153	48,742	3.22

Source: GoP (2026). Aggregate yield is calculated as food-grain production divided by food-grain area; it is not a separately published PBS aggregate-yield series. The 2025-26 values are provisional.

Table 5. Trend diagnostics and correlation tests for annual LUI, 2010-11 to 2023-24 excluding 2018-19 (n = 13)

Test / statistic	Estimate	95% CI	p-value
LUI, mean (%)	73.17 (SD 0.35)	72.95 to 73.38	–
LUI trend, OLS (percentage points per year)	0.016	−0.037 to 0.069	0.51
LUI trend, Newey–West HAC (lag 1)	0.016	−0.017 to 0.049	0.31
LUI trend, Newey–West HAC (lag 2)	0.016	−0.015 to 0.047	0.28
LUI trend, Cochrane–Orcutt (ρ = −0.02)	0.029	−0.029 to 0.087	0.29
LUI trend, Mann–Kendall τ (Sen slope 0.007)	0.03	–	0.95
Durbin–Watson, LUI trend residuals	1.97	dL = 1.01, dU = 1.34	no autocorrelation
Cropping intensity trend (percentage points per year)	0.385	0.089 to 0.681	0.015
Total cropped area trend (million ha per year)	0.142	0.095 to 0.188	<0.001
Correlation: LUI and food-grain production	r = 0.18	−0.41 to 0.66	0.56
Correlation: LUI and aggregate yield	r = 0.11	−0.47 to 0.63	0.71
Detrended correlation: LUI and production	r = −0.04	−0.58 to 0.52	0.90
Detrended correlation: LUI and yield	r = −0.25	−0.70 to 0.35	0.41
First-difference correlation: LUI and production (n = 11)	r = −0.24	−0.73 to 0.42	0.48
First-difference correlation: LUI and yield (n = 11)	r = −0.51	−0.85 to 0.13	0.11

Source: Authors' calculations from GoP (2026). CI = confidence interval; HAC = heteroskedasticity and autocorrelation consistent; dL and dU = lower and upper 5% Durbin–Watson bounds for n = 13. Trend slopes are per calendar year. First differences use consecutive years only (n = 11).

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4. DISCUSSION

This chapter explains the results based on the literature review and constraints on the official data. There are three important outcomes. The national LUI remained unchanged over the last 15 years despite an increase in food-grain production of approximately 42 per cent. LUI is systematically different by farm size, with small and medium farms having higher levels of LUI than large farms. The differences in farm size between large farms and the rest decreased significantly between the two censuses.

The trend of the National LUI between 2010-11 and 2024-25 (P) was not significant, and had no consistent direction, from 72.54 to 73.68 percent with no significant trend. Production continued to increase with food-grain production increasing by 42 per cent while cultivated area and culturable waste remained close to the beginning levels (Table 1), and cropped area increased primarily due to increase in cropping intensity (Figure 2). What one should expect if the land frontier has been reached. Approximately 25% of the culturable area was in culturable waste throughout the study and water is a prerequisite for utilizing this waste since Jehangir et al. (1998) indicated that increase in water potential can increase cropping intensity in the Rechna Doab and that culturable waste can be put to use as an additional cultivated area. If land area is not easily expandable, additional production must be achieved through intensification rather than extensification, that is through increasing the frequency of cropping and/or the yields of existing land. There is no correlation between annual LUI and production or yield that could be found in this reading. LUI changes are primarily attributed to the decisions regarding the fallowing or recording of the crops, while production changes are due to weather conditions, availability of water, and prices and the use of inputs (Jadoon et al., 2025; Iqbal et al., 2026). The tests are feeble, however. With 13 annual observations power is low, and correlations between levels of trending series can mislead (Yule, 1926). We do not, therefore, make any causal claim and the data can be consistent with a “small effect” that this sample cannot measure.

The census comparison provides a better view of differences across farm size. In both census years, the LUI of small and medium farms was higher than the LUI of large farms and this is in line with the hypothesis that smaller farms are likely to use their land more intensively. Sial et al. (2012) attribute this to use of family labor; Jehangir et al. (1998) mention that negative farm size–productivity relationships may be obtained by varying the way the farms are grouped; Mahmood and Haque (1981) warn that the relationship between farm size and productivity may vary according to the manner of grouping farms. Such non-linear patterns may be concealed in our three broad groups. It is more difficult to account for the increase in LUI on large farms from 62.5 percent to 84.3 percent and the reasons behind the increase in LUI cannot be determined with the data available here. The provincial picture is highly skewed with an increase of +32.3 points in Balochistan and +13.1 points in Punjab, but only +3.4 points in KP and in Sindh; Large-farm LUI was 96.2 percent in Punjab in 2024, compared with 74.0 percent in Sindh and 72.2 percent in KP. The national group figure is calculated from area totals in the various provinces, so that a large change in one province, and especially in Balochistan which was based on a very low area total, can swing the national average a great deal.

There are several possible explanations and future experiments that could be performed to test these. Firstly, there has been an increase in water source availability, such as an increase in canal water or tubewells, which would have enabled previously uncultivated areas of large holdings to be cultivated. Farming relies heavily on groundwater in Balochistan, where the LUI doubled to very high values, and recent evidence has suggested over-extraction of scarce groundwater in Balochistan (Iqbal et al., 2024), so the gains may not be sustainable. Secondly, landholding patterns: where larger holdings contain "marginal" land that may not be suitable for cultivation, and small changes in water access (or in the definition of culturable waste) can result in large changes in the ratio; a shift in the distribution of holdings within the large class changes the group average (Naseer et al., 2016; Lowder et al., 2016). Thirdly, mechanization, land preparation is highly mechanized in Pakistan while sowing, transplanting and harvesting are less mechanized (Mahmood et al., 2025) and mechanization has been found to be correlated with the improved farm performance among the mechanization farmers of Punjab (Yasar et al., 2024). The data do not include any information about the use of machinery, and mechanization may have enabled the large operators to grow land that was not grown by other operators for lack of labor or time. Fourth, the regional environmental constraints like water scarcity, salinity and waterlogging could help explain such a low level of LUI on large farms in Sindh and KP as compared to Punjab. Lastly, a portion of the change might be due to a sampling or reporting (Section 2.3.2) effect. These factors were not measured in this study and thus are provided as hypotheses and not findings.

The farm-level averages presented for the 2024 Census have the same ordering by farm size (small above medium above large) in all provinces, but the base for this ordering is different: farm-level average intensity and the number of estimated farms, not the ratio of total cultivated area to total culturable area. The published class averages with farm weights nationally are approximately 97.8 percent, and with area weights are approximately 95.3 percent, the

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same as the headline for the PBS. For this reason, the number of farms is considered as an indicator that is best used in conjunction with other indicators and is not used to measure change between 2010 and 2024.

There's a distinction between production and productivity, as well as between their evidence. The yield of derived aggregate food grains continued to increase, at an average of approximately 0.057 tonnes per hectare per year, but this increase was not due to LUI. The disparities in changes in total food grain production across crop sectors as documented in the Economic Survey (2026) and Jadoon et al (2025) are another indication that the overall production of foodgrains cannot be used as a complete indicator of agricultural productivity. Additionally, the presentations made here are descriptive. We did not formally test for structural breaks and do not separate out the within and between group (composition) changes in LUI. Intensified harmonization of census indicators would enable a clearer message on structural change through time and longer series to compare.

A further constraint is the consistency of the official annual series. Note that the definition of cultivated area used in the Economic Survey is different from the one used in the several published rows: it includes net area sown plus current fallow. The two parts summed, for example, amounts to 22.12 million hectares in 2014-15 but the published value for cultivated area is 23.24 million hectares and the published totals for 2016-17 to 2019-20 do not tally closely either. The published figures for the area of the crops cultivated and Figures showing how much waste may be turned into useable product are the main figures used in the calculations made annually with the aid of the LUI. The annual trend and associations remained unchanged in a second sensitivity calculation where the cultivated area was reconstructed from the 1997-2016 data, but with a range of LUI greater (around 72.72–75.91 percent). The following sensitivity results should not be used as a substitute for the primary series as the source components are not mutually consistent.

Limitations. There are four limitations which should be remembered. The number of independent observations in the annual series is small (13), which causes the tests to be relatively weak and confidence intervals for the trend as well as the correlations are rather wide. The 2018-19 and 2024-25 rows repeat earlier years, and the 2024-25 and 2025-26 values are provisional. Coverage for the two censuses may have varied, there may have been differences in definitions and estimation (see Section 2.3.2), and because no standard errors were available for census tables, the census comparison is not subject to a measure of uncertainty. Lastly, the study relies on national or provincial aggregates and contains no microdata from the farm level or irrigation/exogenous information on machinery or inputs and excludes/excludes separation of explanations discussed above.

5. CONCLUSION AND RECOMMENDATIONS

The conclusions listed below are derived from the results shown above, and there are specific results that are tied to the recommendations.

Conclusions

1. National LUI was stable between 2010-11 and 2024-25 (P): it ranged from 72.54 to 73.68 percent, averaged 73.17 percent (95% CI 72.95–73.38) and showed no significant trend. But the intensity of cropping increased at about 0.39 percentage point per year. The growth in recent years, therefore, seems to be achieved through a more frequent crop rotation on the same land, from improved yield, and not through increased area under cultivation.
2. Based on one area-based formula, LUI is also larger in small and medium farms, than large farms in both 2010 and 2024 as shown in the census comparison. Thus, there was little change in the levels of LUI among small and medium farms, whereas it increased among large farms by 20.8 points from 62.5 to 84.3, the highest rise being observed in Balochistan (+32.3) and Punjab (+13.1). This is descriptive evidence, and subject to the comparison's restrictions of the two censuses and will not imply causes. These farm-level averages (98.4, 95.7 and 91.2 percent) are not comparable and are separate indicators.
3. The production of foodgrains increased from 34.302 MT in 2010-11 to a level of 48.742 MT in 2025-26 (P) which is 42.1 percent of the increase. Neither production ($r = 0.18$) nor yield ($r = 0.11$) were significantly related to Annual LUI, nor were they after detrending and first differencing. This is an absence of evidence and not an absence of a relationship and no causal conclusion can be drawn as the sample is small and the power is low.
4. Main straightforwardness constraint is the brief and partly repeated annual series, issues during the comparability may be some between the two censuses, and the lack of information on inputs, mechanization and irrigation. The district and/or farm level panels could be employed, irrigation effects added to the explanatory variables, formal approaches taken to test the significance of structural breaks, and between-

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group differences and changes in LUI between groups broken down into within-group and composition effects in future research.

Recommendations

The recommendations are based on the above findings.

1. Agricultural and irrigation departments of the provinces should consider provincial procedures for design of interventions, to understand, on a province-by-province basis, why this land is not being cultivated (water availability, salinity, waterlogging, land leveling and financing). It is not possible to provide single factor explanations for differences across provinces.
2. Since the growth of output was due to increased cropping frequencies and yields, governments should increase extension services provision and farmers' access to water use efficiency, mechanization, capacity to access tools and credit and certified seed. This should be accompanied by soil conservation, balanced fertilizer application and saving water, thereby averting deterioration of long-term ambient land and water qualities, especially in groundwater dependent regions like Balochistan.
3. Adults should be targeted by farm size - large farms have lowest LUI and less uniform by province as described above. Access to irrigation and land constraints take priority for large farms in KP, where access to LUI was 72-74 percent in 2024, as well as in Sindh. Special considerations should be given to increasing yields and to making inputs available, rather than to adding land on to small farms, where the LUI is already high, at 95-98 percent.
4. To ensure consistency in providing comparisons across years and across multiple increments of data: PBS, Ministry of National Food Security and Research (MNFSR) and the provincial departments should ensure that values for components are verified with known identities prior to their publication, ensure uniformity of the definition of cropped area, cultivated area, and culturable waste across future agricultural censuses, and publish standard errors. Other tools such as remote sensing and geographic information systems can be used to supplement census data on tracking land conversion change, cropping patterns and sustainable land use management.

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Declarations

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