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SPATIO-TEMPORAL ANALYSIS OF AGRICULTURAL DEVELOPMENT IN DIMAPUR DISTRICT, NAGALAND

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Abstract

This study explores the spatio-temporal aspects of agricultural development, focusing on the dynamic interchange between space and time in shaping agricultural practices and outcomes, utilizing diverse datasets and methodological approaches to discern patterns and trends in the Dimapur district of Nagaland. Highlighting a multidisciplinary approach, it examines how geographical factors, such as land availability, area, production and productivity interact with temporal variables, including economic fluctuations and demographic changes, to influence agricultural development. Through a combination of spatial and temporal analysis, the study investigates patterns of agricultural productivity, land use dynamics, consumption and production patterns, and livelihoods across different regions and periods of the Dimapur district. The study is based on both a primary survey of 125 respondents and secondary data. The analysis suggests that there has been an improvement in agricultural development from 2010 to 2019, with annual variability. The production cluster in the district is mainly comprised of pineapple, banana, paddy, cashew and oil seeds. The crop production data shows that cereals saw a 62% increase in production and a 53% rise in productivity, despite a 5% decrease in cultivated area. The strong correlation between area and production (.913) suggests that the area under production is a key factor in the overall production. Land Use / Land Cover mapping for 2017 and 2023 demonstrates a notable change in land use categories. Despite the built-up areas increasing significantly (3.96%), agricultural productivity showed notable improvements from 2010 to 2019. This study aids in understanding agricultural trends, challenges, and opportunities in Dimapur and offers comprehensive insights that potentially guide future agricultural development and resource management strategies.

Keywords: Spatio-Temporal, Agricultural Development, LULC, Production, Productivity

1. Introduction

Over the past several decades, global agricultural production has witnessed remarkable growth, driven by technological advancements, improved farming practices, and supportive policies. According to the Food and Agriculture Organization (FAO, 2021), Global cereal production increased from 876 million tonnes in 1961 to 2,990 million tonnes in 2019. Meat production rose from 71 million tonnes in 1961 to 337 million tonnes in 2019. Milk production more than doubled from 344 million tonnes in 1961 to 883 million tonnes in 2019. This substantial increase in agricultural output has been crucial in meeting the food demands of a growing global population, which increased from 3.1 billion in 1961 to 7.7 billion in 2019. The Green Revolution, beginning in the 1960s, played a pivotal role in this agricultural transformation. However, this impressive growth has not been without challenges. The intensive agricultural practices associated with the Green Revolution have led to environmental concerns, including soil degradation, water pollution, and loss of biodiversity (Pingali, 2012). Additionally, climate change poses a significant threat to global food security, with changing weather patterns and extreme events affecting crop yields and agricultural productivity (Lobell et al., 2011).

In India, agriculture remains a cornerstone of the economy and society, contributing 18% to the Gross Domestic Product (GDP) and employing 50% of the country's workforce (NITI Aayog, 2017). The sector has undergone significant transformations since independence, with the country moving from food scarcity to food surplus. According to the Ministry of Agriculture and Farmers Welfare (2022), India's food grain production has seen a remarkable increase, rising from approximately 51 million tonnes in 1950-51 to over 305 million tonnes in 2020-21. This growth has been accompanied by diversification in crop production, with notable increases in the cultivation of horticultural crops, oilseeds, pulses, and cash crops like cotton and sugarcane (Indian Council of Agricultural Research, 2022).

The northeastern region of India, comprising seven states including Nagaland, presents a unique agricultural scenario. The region is characterized by hilly terrain, high rainfall, rich biodiversity, and a prevalence of traditional farming methods (Bujarbaruah and Bhatt, 2006). One of the most prominent agricultural practices in the region is shifting cultivation, locally known as jhum. This traditional method involves clearing forest areas, cultivating for a short period, and then allowing the land to regenerate (Ramakrishnan, 2015). While culturally significant, jhum cultivation has been associated with soil erosion, deforestation, and declining productivity due to shortened fallow periods (Grogan et al., 2012).

Dimapur, the largest city in Nagaland, presents a microcosm of the agricultural challenges and opportunities in the northeastern region. With approximately 70% of its population engaged in agriculture, the sector plays a crucial role in the local economy and food security (Government of Nagaland, 2021). However, agricultural practices in Dimapur are predominantly rain-fed, making crop production highly dependent on monsoon patterns (Murry and Das, 2021). Economic growth, rising earnings and urbanization have impacted

Dimapur's dietary patterns. There is expanded demand for more variety assortment in food decisions, and people of Dimapur are turning out to be more worried about food quality and well-being (Jaiswal et al., 2023). The agricultural landscape of Dimapur is characterized by a mix of traditional and modern farming practices. While rice remains the primary crop, there has been a gradual shift towards cash crops and horticultural produce in recent years (Mondalb, 2014).

While extensive research exists on global and national agricultural trends, there is a significant gap in understanding the localized agricultural dynamics in Dimapur, Nagaland. Few studies have examined the spatio-temporal changes in agricultural practices, land use patterns, and food security challenges specific to this region. The unique geographical, climatic, and socio-economic conditions of Dimapur necessitate a focused study to inform targeted agricultural policies and interventions (Singh et. al, 2020). Provides a comprehensive analysis of the spatio-temporal changes in agricultural land use in Dimapur over the past decades, considering the impact of urbanization and changing farming practices. Investigates the impact of changing dietary patterns and urban food demands on local agricultural production and farmer livelihoods (Kuotsuo et. al, 2014). Explores sustainable agricultural strategies that are tailored to Dimapur's unique context, balancing productivity, environmental conservation, and socio-economic development (Briassoulis, 2020). Thus, the study aims to analyse the spatio-temporal changes in agricultural land use in Dimapur over the past decades.

2. Materials and Methods

2.1 Study Area

Dimapur district, often referred to as the 'rice bowl of Nagaland', is situated in the southwestern part of Nagaland state, India. The district lies between 25° 48' and 26° 00' North latitude and 93° 30' and 93° 53' East longitude (Government of Nagaland, 2022). It shares borders with Kohima district to the East, Peren district to the South, and Assam state to the North and West (Directorate of Economics and Statistics, 2021). Dimapur experiences a subtropical monsoon climate, characterized by distinct seasons. The average annual rainfall is approximately 1,500 mm, with about 80% occurring during the monsoon season from June to September (Indian Meteorological Department, 2021). Temperature ranges from 12°C to 36°C throughout the year, with relative humidity fluctuating between 60% and 90% (Directorate of Economics and Statistics, 2021).

2.2 Data Sources

This study is based on both secondary and primary data. The Primary data was collected from 125 respondents, which comprised households and families living in Dimapur, both in urban and rural areas. The collection of data was done through simple random sampling and the snowball technique. The secondary datasets such as area, production and productivity, consumption of fertilizers, land use, distribution of work, workforce participation, production and requirement of crops etc. are drawn from numerous data sources including Statistical Abstract of Nagaland, Indiastat.com, Reports of Agriculture District office, Department of agriculture and family welfare, ICAR, Nagaland, and District agricultural office, Nagaland. Land use/land cover (LULC) changes from 2017 to 2023 were assessed using images derived from Sentinel-2 with 10-meter resolution. The administration boundary of the study area is extracted from the Survey of India, which was further converted into a digital format using ArcGIS, with the projection set to Universal Transverse Mercator (UTM).

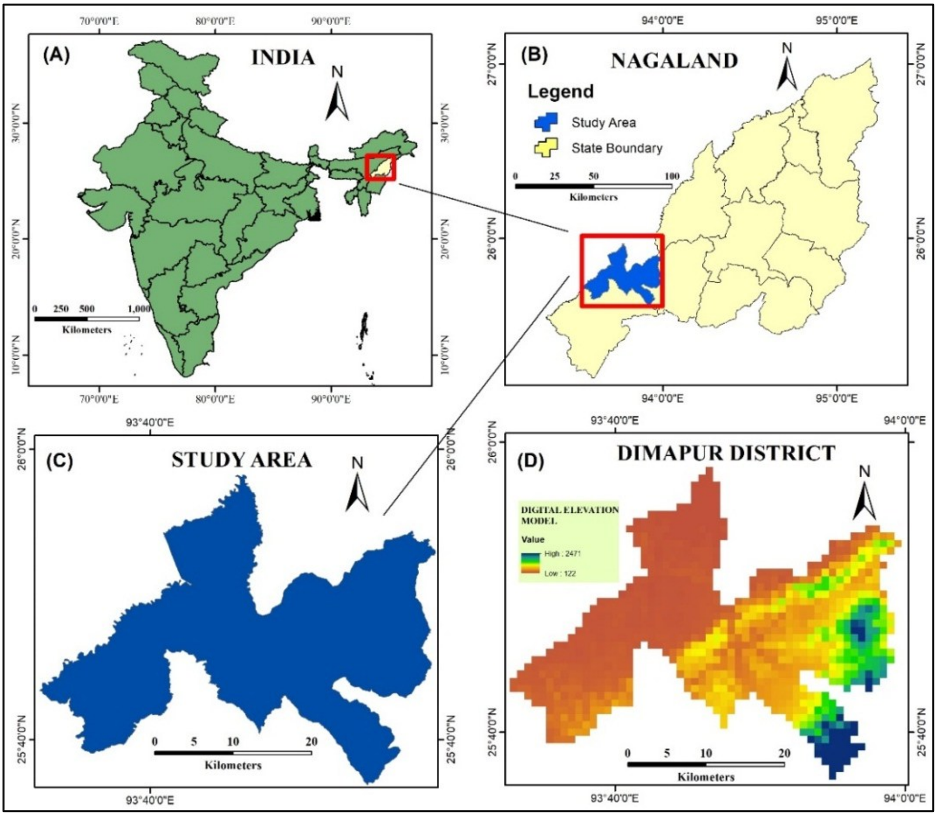

Fig: 1 Location Map of Dimapur District

Source: Census of India and Digital Elevation, 2021

2.3 Land use/land cover (LULC) changes

Land Use / Land Cover maps for 2017 and 2023 were prepared using a supervised classification technique (Fig. 2). An accuracy assessment for LULC classification was done in ArcGIS using the random points, ensuring representation for each LULC class. The overall accuracy, producer's and user's accuracies, and the Kappa coefficient were computed separately for 2017 and 2023. The overall Kappa accuracy for 2017 was 87 per cent and 96 per cent for 2023.

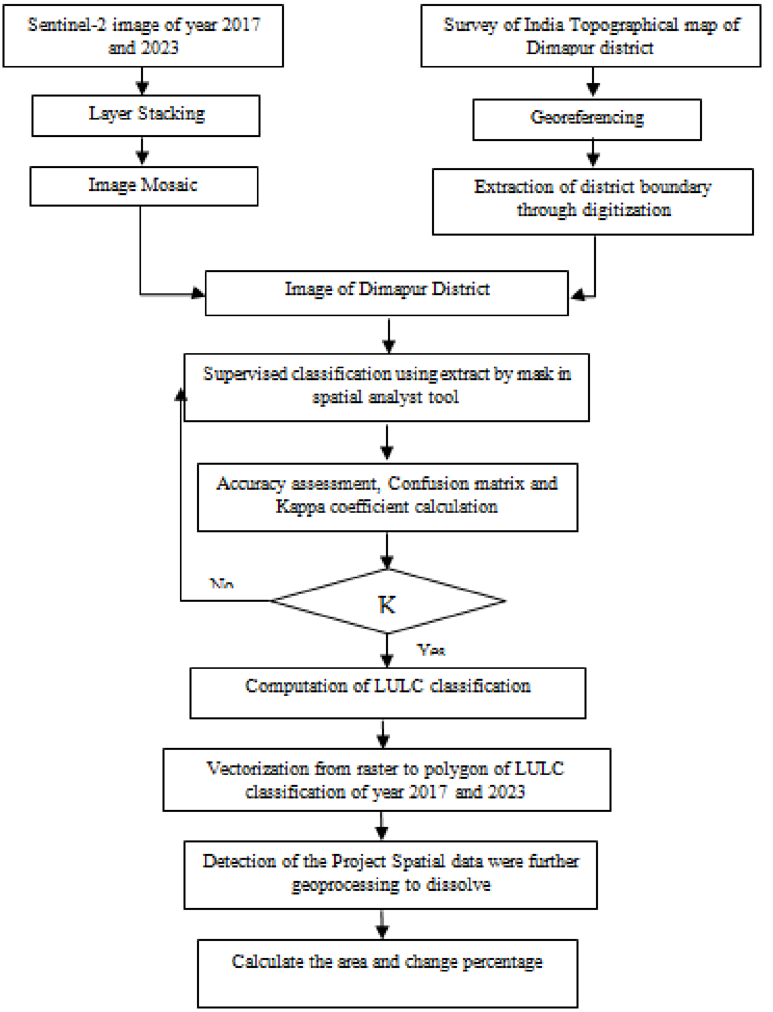

Fig: 2 Methodology Flowchart for LULC Mapping

2.4 Statistical analysis

The secondary data were analyzed using simple averages, ratios, correlation, two-tail tests, correlation and percentage change methods. The percentage change for area, production and productivity for crops from 2010 to 2019 was calculated. Correlation measures were used to understand the strength and direction of the linear relationship between two variables. The formula for Pearson correlation coefficient (*r*) is as follows:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

Where

r is the Pearson correlation coefficient.
x_i and y_i are the individual data points of the two variables.
x and $\overline{y}$ are the means of the two variables, respectively.
n is the total number of data points.

A paired sample test, also known as a paired sample t-test, is used to compare the means of two related groups. In the context of agriculture, a paired sample test compares the means of two related variables, such as area, production and productivity, before and after an intervention, or in two different conditions.

Calculated the standard deviation of the differences. This represents the variability of the differences around the mean.

$$\bar{d} = \frac{\sum_{i=1}^{n} d_i}{n}$$

$$s_d = \sqrt{\frac{\sum_{i=1}^{n}(d_i - \bar{d})^2}{n-1}}$$

Where

s_d is the standard deviation of differences.
di is the difference for each pair of observations.
$\bar{d}$ is the mean difference.
n is the number of pairs.

Calculated the t-statistic using the mean difference and standard deviation of differences:

$$t = \frac{\bar{d}}{s_d/\sqrt{n}}$$

Where

t is the t-statistic.
$\bar{d}$ is the mean difference.
s_d is the standard deviation of differences.
n is the number of pairs.

The critical value of the t-distribution for the desired significance level and degrees of freedom (which is $n-1$). Compare the calculated t-statistic to the critical value to determine whether to reject/accept the null hypothesis.

If $|t|>t_{\alpha/2}$, reject the null hypothesis.

If $|t| \leq t_{\alpha/2}$, fail to reject the null hypothesis.

3. Results and Discussion

The study examines spatial patterns of land use, distribution of workforce participation, crop production disparities, and household consumption patterns.

3.1 Spatial pattern of Land use and agricultural productivity

Understanding cropping patterns provides insights into agricultural practices, seasonal variations, and crop rotation strategies (Shah et al., 2021). Assessing land management practices such as irrigation, fertilization, pest control, and soil conservation techniques is crucial for optimizing agricultural productivity and sustainability in Dimapur (Mozhui and Sharma, 2020).

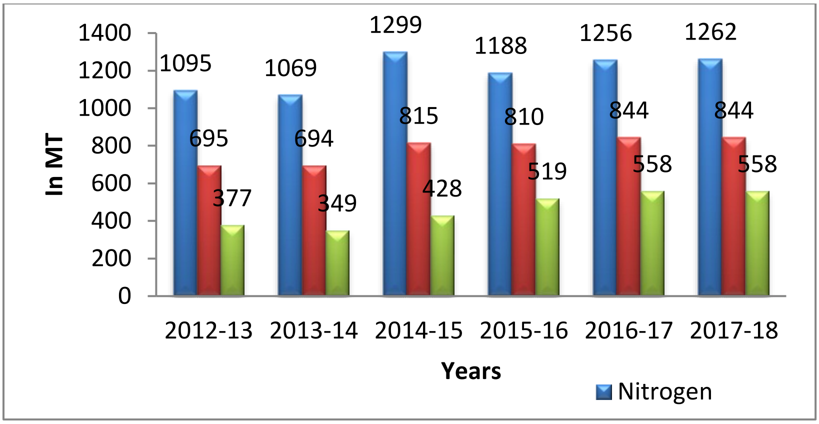

Fig: 3 Consumption of Fertilizers

Source: Directorate of Agriculture, Nagaland, 2018

The consumption of fertilisers in Nagaland, where the average consumption of Nitrogen (N) is around 1000 MT, has fluctuated quite significantly over the years. The highest consumption was 1299 MT in 2014-15, and 1062 MT in 2017-18 was the lowest. Phosphorus (P) consumption is increasing substantially, with 694 MT and 844 MT in the years 2013-14 and 2016-17, as the highest and lowest, respectively. While in Potassium (K), from 2012-13 onwards, the consumption increased from 349 MT to 558 MT(Fig.3).

Table: 1 Land Use Status (preceding average of 5 years from 2013-18) (Area in Ha.)

Districts	Geographical Area	Land under NonAgri use	Tree/ Forest Area	Rainfed area under		Land under tree groves and crops	Current fallow	Other fallow	Net Sown area	Net area sown more than once	Net irrigated area	Gross cropped area
				Cultivated	Cultivable waste							
Dimapur	92700	8200	42200	18470	13910	5850	1670	2400	18470	2234	14635	20704
(Percentage)	5.59%	14.64%	5.50%	10.44%	6.89%	71.10%	1.34%	0.74%	10.44%	97.64%	23.93%	11.55%
Nagaland	1657900	56022	767733	176949	201873	8228	124361	322736	176949	2288	61152	179237

Source: Directorate of Agriculture, Nagaland, 2019

Even though all the net sown region isn't utilized for the production of food, the weighted net sown region shows the accessibility of land that can be utilized for food processing and production. The land use statistics, based on average preceding of 5 years from 2013-18, in Dimapur is presented in Table 1. About 5.59 per cent of Nagaland's geographical area is in Dimapur with 42,200 ha under total forest area, around 12 per cent under gross cropped area. The production cluster in Dimapur is mainly comprised of pineapple, banana, paddy, cashew and oil seeds. The processing cluster is dependent on the raw material for the final products. The major processing clusters in Nagaland are paddy, sugarcane, tea, milk and meat. Apart from the major processing, the minor processing clusters are also there with very small quantities which can't be processed in the clusters (Krishna, 2020).

The Land Use / Land Cover data from 2017 to 2023 demonstrates notable changes in land use categories (Figure 4 and Table 2). The area covered by water decreased from 5.08 km² to 2.82 km², a reduction of 2.26 km², equating to a 0.30 per cent decrease. Tree cover reduced from 501.25 km² to 476.81 km², a loss of 24.44 km², or 3.21 per cent. This decline results from deforestation for agriculture, urban expansion and logging activities. The reduction in tree cover is concerning due to its implications for biodiversity, carbon sequestration, and ecosystem health. The area used for crops decreased from 140.91 km² to 130.85 km², a reduction of 10.06 km², or 1.32 per cent. This could reflect shifts in agricultural practices, urban sprawl into farming areas, or changes in crop viability due to environmental factors. There was a substantial increase in built-up areas from 106.16 km² to 136.35 km², an addition of 30.19 km², or 3.96 per cent. This growth highlights significant urban expansion, likely driven by population growth, economic development, and infrastructure projects. The bare ground almost disappeared, decreasing from 0.06 km² to virtually zero. This reduction suggests that previously bare areas have been repurposed, possibly for development or reforestation.

Table: 2 Dimapur Land Use Land Cover Change from 2017 to 2023

Category	Land Use Land Cover 2017		Land Use Land Cover 2023		Change in LULC	
	2017 (in Km²)	In Per cent	2023 (in Km²)	In Per cent	Change from 2017 to 2023 (in Km²)	Per cent change
Water	5.08	0.67	2.82	0.37	-2.26	-0.30
Trees	501.25	65.75	476.81	62.55	-24.44	-3.21
Flooded Vegetation	0.04	0.01	0.13	0.02	0.09	0.01
Crops	140.91	18.48	130.85	17.17	-10.06	-1.32
Built-Up Areas	106.16	13.93	136.35	17.89	30.19	3.96
Bare Ground	0.06	0.01	0.00	0.00	-0.05	-0.01
Rangeland	8.81	1.16	15.35	2.01	6.54	0.86
Total	762.31	100.00	762.31	100.00		

3.2 Distribution of workforce participation

The workforce participation rate in 2011, at all Indian levels, for males and females was 53.26 and 25.51 per cent, respectively. The distribution of category-wise workers in Dimapur is presented in Table 3. It is observed that the overall main workers are around

1,22,358, which is 16.51 per cent of Nagaland. The total cultivators in the district is around 20,000, which is about 5 per cent of Nagaland. The total agricultural labourers in Dimapur are around 19.96 per cent, of which 21.27 per cent are male and 18.23 per cent are female.

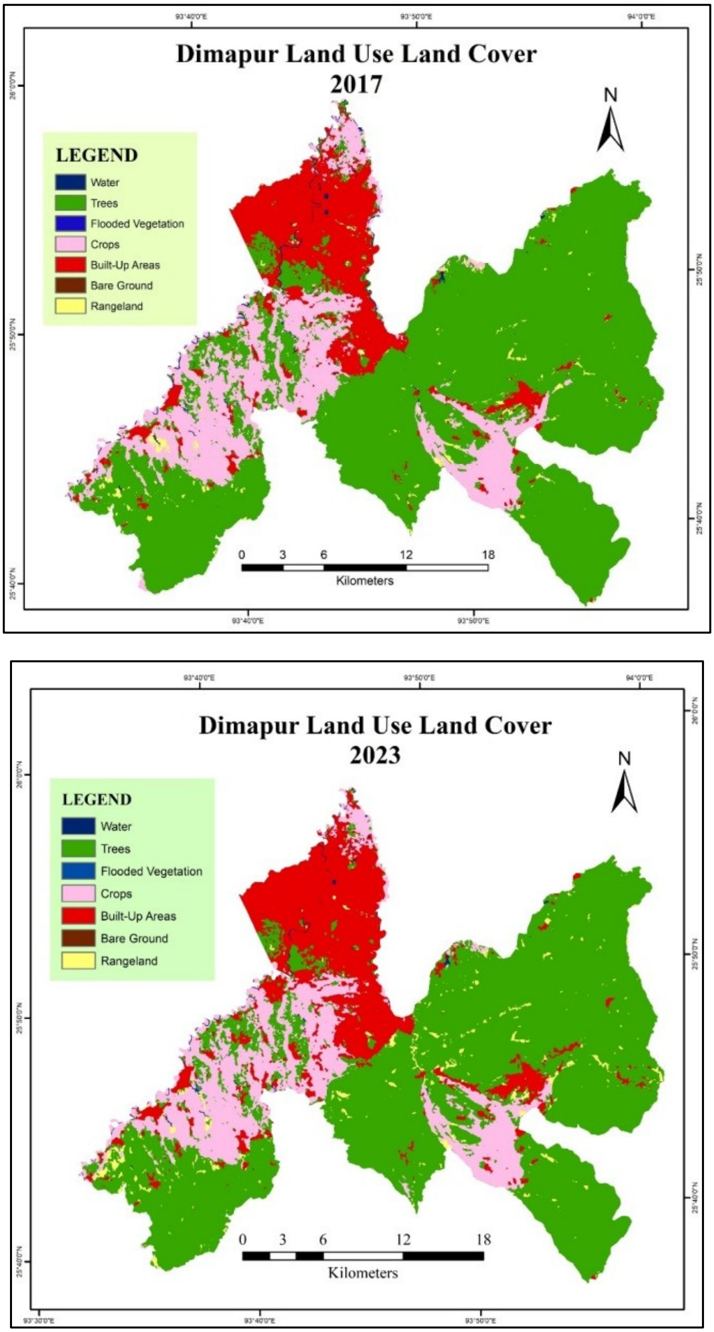

Fig. 4: Dimapur Land Use Land Cover (2017 and 2023)

Table 3: Distribution of Workers

State/District	Agricultural Labourers			Cultivators			Other workers			Grand Total		
	Male	Female	Person	Male	Female	Person	Male	Female	Person	Male	Female	Person
Dimapur	2743	1763	4506	12140	8451	20591	73172	24089	97261	88055	34303	122358
(%)	21.27%	18.23%	19.96%	5.83%	3.98%	4.90%	33.10%	31.23%	32.61%	19.91%	11.47%	16.51%
Nagaland	12899	9672	22571	208221	212158	420379	221084	77145	298229	442204	298975	741179

Source: Directorate of Census Operations, 2011

The work participation rate in 2011 in Dimapur was 40 per cent, which is lower than Nagaland's participation rate. The distribution of total population, main workers, marginal workers and work participation rate for Dimapur and Nagaland is presented in Table 4.

Table 4: Work Participation Rate in 2011

State/ District	Total Population	Total Workers	Marginal Workers	Main Workers	Work Participation Rate
Dimapur	378811	151350	28992	122358	40
(Per cent)	**19.15%**	**15.54%**	**12.45%**	**16.51%**	-
Nagaland	**1978502**	**974122**	**232943**	**741179**	**49**

3.3 Crop production patterns

There are two kinds of cereal production frameworks engaged in the study area: 1) wet rice culture - both HYV and traditional varieties used in irrigated and rain-fed conditions in terraces, plains and fields, and 2) shifting (Jhum) cultivation of traditional varieties in rain-fed conditions of slope/hill areas (Baruah et al., 2014). The traditional Jhum cultivation is a unique agricultural practice in the study area. In this method, a mixed cropping pattern is practised by joining grains, pulses, oilseeds, crops and spices utilising local cultivators, which are natural or organic (Pratap, 2011).

Table 5: Percentage change in area, production and productivity in 2010 and 2019

Crops	2010			2019			Per Cent Change (%)		
	Area (ha)	Prod. (MT)	Productivity	Area (ha)	Prod. (MT)	Productivity	Area (ha)	Prod. (MT)	Productivity
Cereals	22708	31791	1.4	21477	51540	2.14	-5%	62%	53%
Pulses	1880	1880	1	2012	2989	1.3	7%	59%	30%
Oil seeds	10185	8454	0.83	11204	13444	1.2	10%	59%	45%
Vegetables	2945	10308	3.5	3178	22092	6.8	8%	114%	94%
Fruits	2800	9800	3.5	3166	16448	5.3	13%	68%	51%

Source: Department of Agriculture and allied departments, Govt of Nagaland (2020)

There is an upward trend in cereals production from 31,791 MT in 2010 to 51,540 MT in 2019. Although the cereals area has decreased by 5 per cent, production and productivity have increased by 62 and 53 per cent, respectively. Likewise, the production of pulses, oilseeds, vegetables and fruits in Dimapur has increased considerably in Dimapur district (Table 5). The vegetable production saw a maximum growth of 114 per cent. This could suggest that farmers preferred more diverse crops to meet the local market demands.

There was a strong positive correlation between area and production (0.913), indicating that as area increased, production also increased. A negative correlation is noted between area and productivity (-0.438), suggesting that increases in area and production do not necessarily correlate with productivity improvements (Tables 6 and 7).

Table 6: Correlation Between Area, Production and Productivity in 2010

		Area	Production	Productivity
Area	Pearson Correlation	1	.913*	-0.436
	Sig. (2-tailed)		0.03	0.463
Production	Pearson Correlation	.913*	1	-0.058
	Sig. (2-tailed)	0.03		0.926
Productivity	Pearson Correlation	-0.436	-0.058	1
	Sig. (2-tailed)	0.463	0.926	
*. Correlation is significant at the 0.05 level (2-tailed).				

Table 7: Correlation Between Area, Production and Productivity in 2019

		Area	Production	Productivity
Area	Pearson Correlation	1	0.846	-0.438
	Sig. (2-tailed)		0.071	0.461
Production	Pearson Correlation	0.846	1	0.06
	Sig. (2-tailed)	0.071		0.924
Productivity	Pearson Correlation	-0.438	0.06	1
	Sig. (2-tailed)	0.461	0.924	

The two-tailed tests comparing 2010 to 2019 data for area, production, and productivity show that the changes in area are not statistically significant (p = 0.8), suggesting that the slight increase in area may not have a meaningful impact overall (Table 8).

Table 8: Two-tailed tests between Area, Production and Productivity 2010 and 2019

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Area (2010) Area (2019)	-103.8	822.4	367.8	-1125	917.4	-0.3	4	0.8
Production (2010) Production (2019)	-8856	7194.9	3217.7	-17789.7	77.7	-2.8	4	0.1
Productivity (2010-11) Productivity (2019)	-1.3	1.3	0.6	-2.9	0.3	-2.3	4	0.1

3.4 Consumption Pattern

The socio-economic conditions of the surveyed respondents are presented in Table 9. In this study, it was observed that the size of the families is mainly small to medium. It was observed that households' status and the preferences for food products are variable (Yepthomi, 2016).

The consumption of onions, potatoes, vegetables, legumes, and fruits shows varied patterns as presented in Table 10. Consumption patterns reflect both traditional preferences and changing lifestyles. For instance, most of the surveyed households consume more vegetables monthly, which creates market demand that drives the changes in agricultural cropping patterns considerably in the study area.

Table 9: Socio-Economic Status of Dimapur District

Category	Responses (N=125)
Gender	
Male	62
Female	63
Prefer not to say	0
Education level of household head	
Illiterate	06
5 Years of schooling (Primary)	06
8 Years of schooling (Middle)	08
10 years of schooling (High)	09
12 years of schooling	24
Graduation	43
Masters	26
Others (Diploma, etc.)	03
Household Income (Annually)	
Below 1 Lakh	22
1-3 Lakhs	18
3-5 Lakhs	22
5-8 Lakhs	27
8-10 Lakhs	16
Above 10 Lakhs	20
Household family size	
Small (≤4)	67
Medium (5-7)	41
Large (≥8)	17
Tenancy Status of the household	
Owner	57
Tenant	51
Others	17
Residency history of the household	
By Birth	49
Less than 10 Years	24
Between 10 and 20 years	23
Between 20 and 30 years	19
More than 30 Years	10

Table 10: Consumption pattern of households

	Zero Consumption	2 Kg	4 Kg	6 Kg	8 Kg and Above
Vegetables and fruits Consumption in the last 30 days (in %)					
Onion	3	22	31	17	26
Potato	3	17	38	17	25
Vegetable	2	13	33	27	26
Legumes	14	34	27	16	13
Fruits	5	17	38	18	23
Dairy Product consumption in the last 30 days					
Milk	5	20	30	11	33
Curd	15	38	22	11	14
Cheese	28	34	22	11	4
Bread consumption in the last 30 days					
Barley	30	38	17	11	5
Rice	2	21	34	18	26
Wheat grain flour	7	27	33	16	17
Food-related Consumption in the last 30 days					
	Zero Consumption	1/2 Kg	2 Kg	3 Kg	4 Kg and Above
Garam Masala	17	67	13	1	2
Butter	22	46	27	4	2
Oil	6	41	30	7	13
Sugar/Jaggery	7	40	31	7	14

Source: Based on primary survey, 2021

4. Conclusion

The study of the agricultural development of Dimapur reveals a complex landscape of challenges and opportunities, characterised by significant changes in land use, agricultural productivity, and consumption patterns. Between 2017 and 2023, the district experienced a 3.21% decrease in tree cover and a 1.32% reduction in cropland, while built-up areas expanded by 3.96%. Despite this urbanisation trend, agricultural productivity notably improved from 2010 to 2019. Crop production data illustrate that cereals saw a 62% increase in production and a 53% rise in productivity, despite a 5% decrease in cultivated area. Vegetables demonstrated the most dramatic growth, with a 114% increase in production and a 94% boost in productivity. Workforce participation in Dimapur (40%) lags behind the overall rate for Nagaland (49%). The study recommends implementing sustainable land use policies to expand agricultural lands and increase workforce participation in the agricultural sector. Investing in agricultural research and technology, particularly promoting crop diversification and value-added vegetable production industries, is essential for the study area. Developing targeted workforce training programs to address the gap in work participation rate and strengthening market linkages to support farmers and contribute to improving food security are also to be considered while planning for sustainable agricultural development in the Dimapur district of Nagaland.

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