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Rice Production in Northeast India: Decomposition and Trend Analysis

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ABSTRACT

The study analyse the Compound Annual Growth Rates (CAGR), instability using Cuddy-Della Valle Index, estimated rice requirement with the projected population till 2035. Decomposition analysis was used to examine how area and yield contributed to the overall production of rice in North Eastern (NE) India. The study was conducted for the period of 54 years (1966-67 to 2019-20) on state-wise area under, production and yield of rice in NE India. The whole time period was divided into three phases *viz*., phase I (1966-67 to 1983-84), phase II (1984-85 to 2001-2002), phase III (2002-03 to 2019-20) making almost two decades each and the overall period as phase IV (1966-67 to 2019-20) based on availability of data. Positive significant growth in area under, production and yield of rice was experienced in NE India during 1966-2019. The study showed that yield effect contribute the most to overall increase in production of rice in the region. The state Tripura has the highest growth in yield of rice (2.59%) with low instability while, Manipur has the lowest growth in yield (0.96%) with medium instability. Among the NE states, five states namely Assam, Manipur, Meghalaya, Mizoram and Sikkim were deficit in rice production during 2019. The total requirement of rice in NE during 2022 and 2035 was estimated to be 7549 thousand MT and 8347 thousand MT (increased by 10.57%), respectively. Thus, the study recommended the application of new agronomic practices and cultivation of improved varieties to increase production and yield instead of increasing area under cultivation considering the scarcity of land.

1. Introduction

Globally, rice is the second essential cereal crop, after maize. Rice contributes 20% of the global dietary energy, whereas 19% and 5% were given by wheat and maize, respectively (Alexandratos and Jelle, 2012). Rice is usually served with pulses (legumes) or other protein-rich dish. In European countries, rice starch is widely used for making intoxicating cocktails. Sake, a popular Japanese beverage, is made by fermenting rice. The intoxicating drinks from rice bran is also produced in India. Other than its consumption as food, the rice-straw can be used for making straw boards, paper, and mats. Furthermore, rice bran oil is used for making soaps and cosmetics. The crop forms the backbone of millions of rural people livelihoods and is crucial for food security.

The total area under rice cultivation is 164.19 million hectare, globally with a total production of 510 million metric tones (MT) in the year 2020-21. China ranked first in the world in rice production during 2021, with a production output of 148.3 million MT, followed by India (122.27 million MT) and Indonesia (35.3 million MT) (Statista, 2022).

Rice is cultivated in India under a broad range of altitude and at elevations ranging from sea level to 3000 meters. The crop grows in hot and humid climate, it thrives well in areas with high humidity, extended periods of sunlight and a steady supply of water. The average temperature necessary for the whole life span is between 21ºC and 37ºC. The crop can withstand a maximum temperature of 40ºC to 42ºC. In India, the total acreage for rice is 43.78 million hectare with productivity of 2.71 tones

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per hectare during 2019-20. During 1980-2014, both production and yield increased at the rate of 5% and 4% per annum, respectively while there was marginal increased (0.48% per annum) in area under rice in India (Laitonjam et al. 2018).

Among the states, Uttar Pradesh (19.139 million MT) ranks first in production of rice followed by Punjab (12.189 million MT) and West Bengal (11.521million MT). The North East India with a total area of 3.238 million hectare under the crop and production of 7.168 million MT during 2019-20 constitute 7.42% and 6.03% respectively to the total area and production of rice in India. Among all the states of NE, the yield of rice is highest in Tripura (3030.75 kg/ha) which is also higher than all India average (2722.49 kg/ha) during 2019-20. The average yield in NE India significantly increased from 919.79 kg/ha in 1966-67 to 2213.17 kg/ha during 2019-20 (GoI, 2021). However, according to Central Rice Research Institute (CRRI), by 2030, India must produce 120 million MT to meet the total population of around 1.5 billion people. In view of this, to make aware the region's contribution to this national need and to help policy stakeholders the present study is to estimate the growth and instability in area under, production and yield of rice and also to study the surplus and deficit of rice in NE states of India.

2. Materials and Methods

Data

Long term time series data on area under, production and yield of rice were collected for the period 1966-67 to 2019-20 (54 years). The analysis spanned across the periods *viz.,* Phase I (1966-67 to 1983-84); Phase II (1984-85 to 2001-02) and Phase- III (2002-03 to 2019-20) and overall period *i.e.* Phase- IV (1966-67 to 2019-20) to have a better understanding of disparity among the phases. However, due to unavailability of data, the analysis commenced from 1970-71 in case of Meghalaya and Mizoram and 1984-85 in case of Sikkim.

Estimation of Growth Rate

The most commonly used methods for estimating growth rate in production are Linear Growth Rate (LGR) and Compound Annual Growth Rate (CAGR). Comparison of growth rates over different time periods, seasonal, cyclical changes and compound effects in time series data were some of the limitations of LGR (Dandekar, 1980). Thus, the use CAGR is more suitable in analyzing growth rate.

$$y=ab^{t}e \quad \text{......................(i)}$$

Equation (i) is converted to logarithmic form which is as follows:

$$\ln Y = \ln a + t(\ln b) + e \quad \text{......................(ii)}$$

Where 'Y' is area/ production/ yield; 't' is the number of years; 'a' is the constant; 'b' = (1+r) is the slope coefficient that measures relative change in Y for an absolute change in explanatory variable; 'r' is growth rate; 'ln' is natural logarithm and 'e' is the error term.

The CAGR is estimated by using the formula given below:

$$CAGR = (\text{antilog } b - 1)*100 \quad \text{..................(iii)}$$

Instability in pulses production

Different techniques can be used to measure the instability of an agricultural region, its productivity, and its yield. Coefficient of variation (CV), Cuddy-Della Valle Index (CDVI), and Coppock Instability Index are the three often employed techniques (CII). Each of these approaches has benefits and drawbacks of its own. The CV is simple to compute, but because it overestimates instability, it has received much criticism. If CV is used to measure instability, for instance, a region with a steady rate of growth will have a high instability rating. In order to measure variability in time series data, many researchers have used the CDVI approach, which is a modicifcation of CV (Bezabeh et al., 2014; Kumar et al., 2017; Bisht and Kumar, 2018; Baviskar et al., 2020). The CDVI de-trend the CV by using coefficient of determination and showing the exact direction of instability (Cuddy and Valle, 1978). Thus, in order to quantify the instability in pulse production in North Eastern states, CDVI was used in the current study. The CDVI is estimated using the following formula:

$$CDVI = CV \times \sqrt{1-\bar{R}^2} \quad \text{.............................(iv)}$$

Where, CV is the coefficient of variation, and $\bar{R}$ is the coefficient of determination from a time-trend regression adjusted for its degrees of freedom. Higher value of the index shows higher instability and vice-versa. CDVI is categorized into low (0<CDVI≥15), medium (15<CDVI ≥30) and high (CDVI >30) instability (Rakesh Sihmar, 2014).

Decomposition Analysis

Changes in the area under a crop and its average yield are fundamentally what determine any change in production. The relative contribution of area, yield, and their interplay to the production of all pulses was calculated using a decomposition analysis model. The following equation was used to carry out the decomposition analysis for the current study (Dupare *et al.,* 2014; Pattnaik and Shah, 2015; Sharma *et al.,* 2017; Singh *et al.,* 2018; Laitonjam *et al.,* 2018):

$$\Delta P = Y_b \Delta A + A_b \Delta Y + \Delta A \Delta Y$$

where, ΔP (change in production)= P_c-P_b; ΔY (change in yield) = Y_c-Y_b; ΔA (change in area) = A_c-A_b; P_b, Y_b, and A_b are the production, yield and area for the base year, respectively; and P_c, Y_c, and A_c are the production, yield and area under pulses for the current year, respectively. By applying the following formula $A_b \Delta Y/\Delta P$, $Y_b \Delta A/\Delta P$, and

ΔAΔY/ΔP, respectively, he contributions of yield area, and their interaction are estimated.

Analysis of surplus or deficit

To have an idea regarding the sufficiency of pulses production in NE India with the growing population, the surplus or deficit analysis was made. The requirement was estimated in each census year beginning from the year 1981 till 2011. This requirement of pulses in the year 2022 was estimated by multiplying the population of the year 2022 (NCP, 2020) with the per capita requirement of pulses (29.2 kg) recommended ICMR.

3. Result and Discussion

Growth in area, production and yield of pulses

The state-wise CAGR in area, production and yield of pulses in NE India during 1966-67 to 2019-20 is presented in Table 1. During Phase I (1966-67 to 1983-84), the CAGR in yield of pulses was negative in Meghalaya and Sikkim but it was not statistically significant. Among the states, the CAGR in area under pulses were positive and statistically significant in Meghalaya (4.39%), Sikkim (14.80%) and Tripura (12.40%), respectively. The growth in production was positive and significant in Meghalaya (4.01%), Nagaland (30.15%) and Tripura (15.01%). There was positive significant growth in yield of pulses only in Tripura (2.32%). In NER, there was positive significant growth in area (5.02%), production (7.56%) and yield (2.42%) of pulses during Phase I of the study period. Thus, this implies that during this time, the time trend had a substantial impact on changes in the area, production, and yield of pulses.

During Phase II (1984-85 to 2001-02), there was significant negative growth in area (Assam, Sikkim and Tripura), production (Assam and Tripura) and yield (Mizoram) of pulses. During this phase positive significant growth in area was observed in Meghalaya (3.90%) and Nagaland (11.84%) while significant positive growth in production was experienced in Arunachal Pradesh (2.93%), Meghalaya (3.94%) and Nagaland (13.21%). In Arunachal Pradesh and Tripura there was significant positive growth in yield of pulses at the rate of 1.65% and 1.57%, respectively. In NER, the growth was positive and significant only in yield of pulses (1.62%) during the study period.

During Phase III (2002-03 to 2019-20), there was significant negative growth in area and production of pulses in Sikkim (-6.68% and -6.32%, respectively) while positive significant growth was observed in Arunachal Pradesh (5.04%), Assam (2.86%), Manipur (8.62%), Meghalaya (7.92%) and Tripura (13.40%). In production of pulses, there was positive significant growth in Arunachal Pradesh (4.39%), Assam (6.05%), Manipur (14.84%), Meghalaya (14.41%) and Tripura (14.49%), while in yield of pulses the significant positive growth was experienced in Assam (3.10%), Manipur (5.73%) and Meghalaya (6.01%) during Phase III of the study period.

The results of the overall period (1966–1967 to 2019–20) reveals positive considerable rise in the area under pulses in Arunachal Pradesh, Meghalaya, and Nagaland, as well as in the production and yield of pulses in those states as well as Assam, Tripura, Meghalaya, and Nagaland. The study found that in NE India there was considerable positive growth in the area (1.53%), production (3.47%), and yield (1.91%) of pulses throughout the course of the study period, indicating that temporal/time trend had a significant impact on these changes.

The instability index in area, production and yield of pulses in all the phases (Fig. 1.) viz., Phase I (1966-67 to 1983-84), Phase II (1984-85 to 2001-02), Phase III (2002-03 to 2019-20) and over all period (1966-67 to 2019-20) was analysed.

In Arunachal Pradesh, there was low instability in area, production and yield of pulses in all the sub-periods. One of the interesting finding in instability analysis is that in Nagaland, there was high instability in early phase (Phase I) while in the later phase, the instability reduced and there was medium and low instability in Phase II and Phase III, respectively in area, production and yield of pulses. Assam experienced medium production and area instability along the same lines, however there was minimal instability in the last period (Phase III). In Manipur, Meghalaya and Mizoram, there was low instability in early period but in the later period, medium instability was observed in area, production and yield of pulses. In Sikkim and Tripura, medium instability in area and production was observed in all the sub-periods (Phase I, II and III).

Contribution of area, yield and their interaction effect on pulses production

The growth of pulses production in NE India was shown in Table 2 by the roles that area and yield played. This was accomplished by dividing the change in pulses into three effects: area, yield, and interaction (both area and yield). In all the sub-periods (Phase I, Phase II and Phase III), area effect contributes the most to change in production of pulses in the states of NE India except in Mizoram. In Phase I, interaction effect i.e., both area and yield effect contribute to increase in production of pulses but in the later phase (Phase II and III) it was yield effect which contribute the most. The analysis of the overall study period revealed that in all the states area effect contribute the most to the change in production of pulses except Assam, Mizoram and Nagaland where contribution to change in production comes from yield effect in case of Assam and interaction effect in case of Mizoram and Nagaland.

Table 1: State-Wise CAGR in Area, Production and Yield of Pulses in NE India (1966-67 TO 2019-20)

State	Phase I (1966-67 to 1983-84)			Phase II (1984-85 to 2001-02)			Phase III (2002-03 to 2019-20)			Over all (1966-67 to 2019-20)		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y
AR	-	-	-	1.26	2.93*	1.65*	5.04***	4.39***	-0.62	3.20***	3.97***	0.75*
AS	2.49	3.22	0.71	-5.26***	-4.54**	0.76	2.86***	6.05***	3.10***	0.13	1.62**	1.49***
MN							8.62*	14.84*	5.73*			
ML	4.39**	4.01*	-0.37	3.90*	3.94*	0.04	7.92*	14.41**	6.01***	2.78***	4.15***	1.33**
MZ				-0.41	-4.71	-4.31*	-1.80	1.98	3.84	-0.77	-1.76	-1.01
NL	23.52	30.15*	5.37	11.84***	13.21***	1.22	1.16	1.37	0.21	9.39***	11.37***	1.80***
SK	14.80**	13.48	-1.15	-4.08*	-3.84	0.26	-6.68*	-6.32*	0.38	-1.81	-1.30	0.53
TR	12.40***	15.01***	2.32*	-5.32*	-3.84*	1.57***	13.40***	14.49***	0.96	1.93	3.54**	1.58***
NER	5.02***	7.56***	2.42**	-2.72	-1.14	1.62**	3.41***	5.43***	1.95***	1.53***	3.47***	1.91***
India	4.62***	5.65***	0.99	-3.63*	-3.03	0.63	1.95*	4.13**	2.14**	-0.18	1.08*	1.27***

A: Area, P: Production, Y: Yield

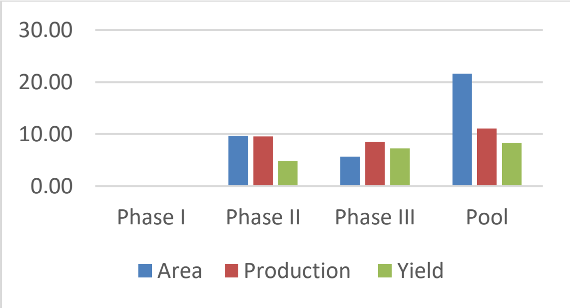
AR: Arunachal Pradesh; AS: Assam; MN: Manipur; ML: Meghalaya; MZ: Mizoram; NL: Nagaland; SK: Sikkim; TR: Tripura; NER: North East Region

*Significant at 0.05 level

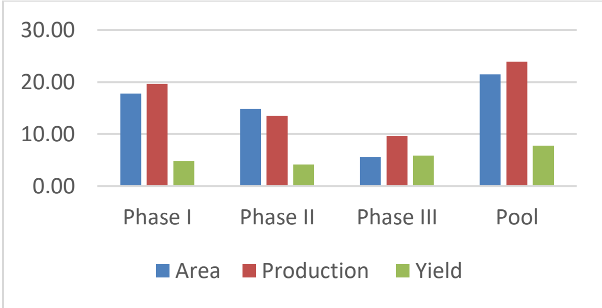
**Significant at 0.01 level

***Significant at 0.1 level

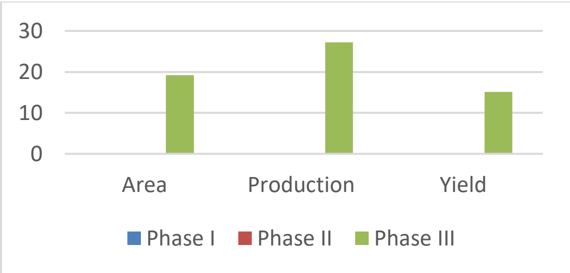
Instability in area, production and yield of pulses



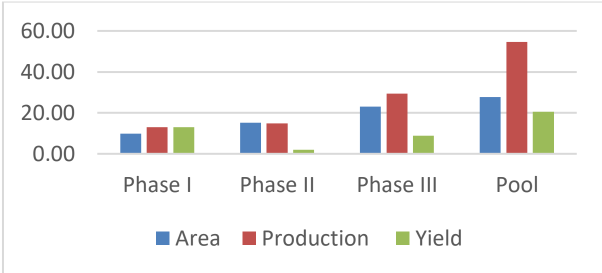
Arunachal Pradesh



Assam



Manipur



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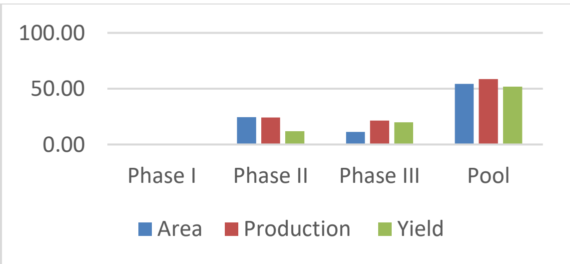
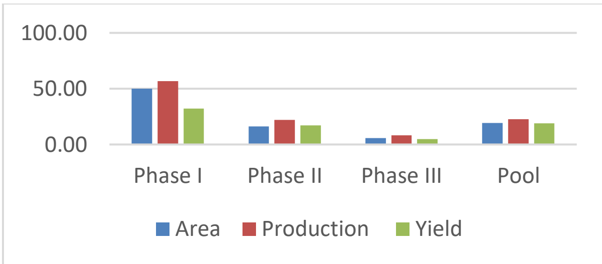
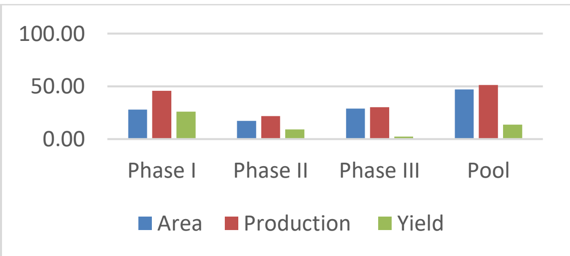


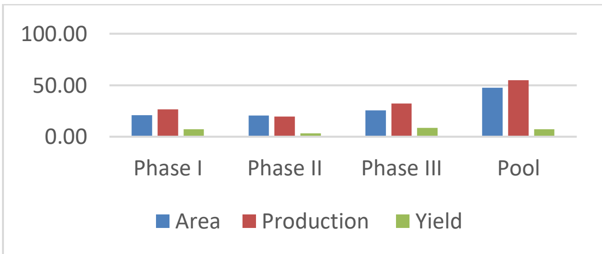
Mizoram



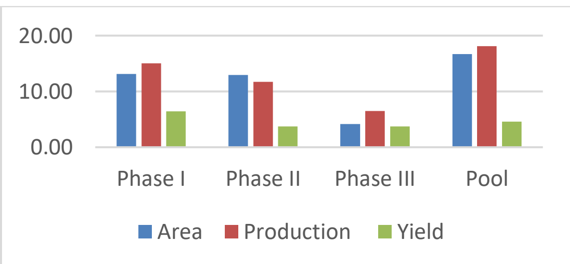
Nagaland



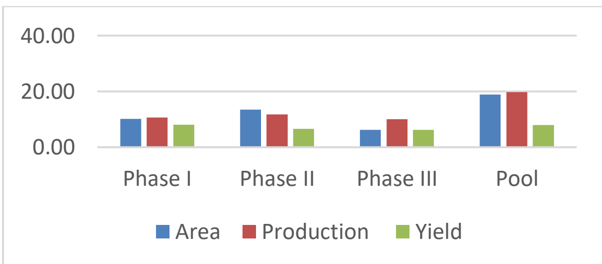
Sikkim



Tripura



North-East



All India

Figure 1. State-wise instability index for area, production and yield of pulses in NE

Table 2. Percentage contribution of Area, Yield and their interaction effect on change in pulses production in NE India

Particular	Phase I (1966-67 to 1983-84)	Phase II (1984-85 to 2001-02)	Phase III (2002-03 to 2019-20)	Over all (1966-67 to 2019-20)
Arunachal Pradesh				
Area effect	-	50.47	137.34	92.72
Yield effect	-	41.63	-21.59	3.17
Interaction effect	-	7.90	-15.75	4.11
Assam				
Area effect	79.04	123.13	43.76	25.88
Yield effect	14.83	-43.57	41.13	51.97
Interaction effect	6.13	20.44	15.11	22.15
Manipur				
Area effect	-	-	43.90	43.90
Yield effect	-	-	19.85	19.85
Interaction effect	-	-	36.25	36.25
Meghalaya				
Area effect	190.55	90.56	40.66	62.12
Yield effect	-49.47	6.58	25.49	7.31
Interaction effect	-41.07	2.86	33.85	30.58
Mizoram				
Area effect	17.54	-11.87	-109.66	20.86
Yield effect	6.51	107.84	273.17	6.15
Interaction effect	75.95	4.02	-63.52	73.00
Nagaland				
Area effect	45.79	84.73	84.69	39.21
Yield effect	13.42	4.73	14.55	5.36
Interaction effect	40.79	10.54	0.76	55.43
Sikkim				
Area effect	77.71	117.76	109.18	196.09
Yield effect	8.54	-29.57	-15.72	-151.94
Interaction effect	13.75	11.81	6.54	55.85
Tripura				
Area effect	72.41	120.62	86.25	52.85

Yield effect	7.57	-41.54	4.15	8.65
Interaction effect	20.02	20.93	9.61	38.50
Northeast				
Area effect	55.56	235.39	61.28	34.25
Yield effect	24.00	-193.65	26.71	27.41
Interaction effect	20.44	58.25	12.01	38.34
All India				
Area effect	74.16	115.66	41.68	22.94
Yield effect	16.42	-23.37	47.31	62.11
Interaction effect	9.42	7.71	11.00	14.95

Deficit/Surplus in pulses production

During 2035, the NE region will require an estimated production of 1669 thousand tonne of pulses for the projected population of 571.74 (Table 3). The estimated requirement of pulses production was highest in Assam (1143 thousand tonne) followed by Tripura (133 thousand tonne) and Meghalaya (107 thousand tonne) for the projected population of 391.58 lakh, 45.44 lakh and 36.70 lakh, respectively. Among the NE states during 2011, 2015 and 2019, there was huge deficit in pulses production in all the NE states. During 2019, the major deficit in pulses was observed in Assam (-899 thousand tonne) followed by Tripura (-98 thousand tonne) and Meghalaya (-82 thousand tonne). The total pulses deficit in the whole NE India was 1235 thousand tonne during 2019 (Table 4).

Table 3. Estimated requirement of pulses as per projected population during 2022, 2025, 2030, 2035 in NE states of India.

States	2022		2025		2030		2035	
	Population (Lakh)	Reqd. (000' tonne)	Population (Lakh)	Reqd. (000' tonne)	Population (Lakh)	Reqd. (000' tonne)	Population (Lakh)	Reqd. (000' tonne)
AR	15.51	45	15.94	47	16.59	48	17.12	50
AS	353.78	1033	363.82	1062	379	1107	391.58	1143
MN	32.01	93	32.89	96	34.24	100	35.32	103
ML	33.26	97	34.17	100	35.57	104	36.7	107
MZ	12.3	36	12.64	37	13.15	38	13.57	40
NL	22.18	65	22.79	67	23.72	69	24.47	71
SK	6.83	20	7.02	20	7.31	21	7.54	22
TR	41.18	120	42.32	124	44.05	129	45.44	133
NEH	517.05	1510	531.59	1552	553.63	1617	571.74	1669

Table 4. Surplus or deficit of pulses in NE states of India (IN 000'TONNE)

States	2011	2015	2019
Arunachal Pradesh	-30	-29	-30
Assam	-846	-853	-899
Manipur	-57	-57	-66
Meghalaya	-83	-79	-82
Mizoram	-27	-28	-29
Nagaland	-23	-17	-16
Sikkim	-12	-13	-14
Tripura	-102	-101	-98
NEH	-1180	-1179	-1235

4. Conclusion

The fact that the NE region's pulse productivity was higher than that of all of India points to the promising future of growing pulse production from this area. NER is one of the potential areas for boosting the output of pulses horizontally by utilising a portion of the 1.67 million ha of shifting agriculture *(Jhum)*. For improving the area under pulses with sufficient irrigation infrastructure, fallow rice and maize can be utilised. The acreage and output of pulses in this region may be raised vertically since they can coexist with other crops and are practical for relay farming with other crops. Short-duration pulses like mung bean and urd bean give the chance to take advantage of the spring and autumn seasons, which are often fallow in this region. Pulses would undoubtedly improve soil fertility in this region's rice and maize-based farming systems in a sustainable manner. Additionally, coordinated efforts from many ministries are required to transition the land under shifting cultivation to the production of pulses and other crops using conservation agriculture principles, which would ultimately help in soil conservation. To improve pulses production and ensure the nutritional security of our nation, particularly this region, extensive demonstrations and training programmes should be implemented at the farmer level.

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