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Quantifying agricultural characteristics using several indicators and extensive field surveys in an ecologically fragile watershed of India

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Abstract

The present research was carried out in an ecologically fragile watershed of North-East India to comprehend the agricultural growth and development by quantifying its status employing several indicators, viz. physiological density, crop diversification, crop intensity and concentration. The study has demonstrated the use of primary data collected through extensive field surveys based on multistage sampling method in conjunction with a relevant secondary database. The findings revealed marked variation within the region in cropping patterns and associated aspects. The physiological density ranges between 1.91 to 85.54, cropping intensity ranges from 69.02% to 186.42%, crop diversification (6.42 to 100.14) and crop concentration (0.32 to 4.49), respectively. Continuous monitoring of the agricultural environment and adopting site-specific crop management practices supported by relevant information would boost the agricultural outcome and sustainability. Thus, the study would assist in framing guidelines to improve the agricultural landscape of the region.

Keywords: agriculture, cropping pattern, productivity, diversification, intensity, concentration, sustainable.

Introduction

Since the beginning of human civilization, agriculture has played a unique role as a thriving economic activity, especially in rural areas. Development of agriculture, along with allied sectors, has been serving as a critical impetus to eradicate poverty, boost shared prosperity and feed the booming population (World Bank, 2023). Endowed with a mosaic of diverse agro-climatic zones accompanied by suitable physiographic condition and abundance of alluvial soil, the agrarian economy of India supports more than half of its population and employs a majority of its workforce (Pandey, 2009; Shah et al., 2021).

Agricultural expansion is one of the key aspects of India's economic development and national food sufficiency plans, but its pace has been impacted by physical, socio-economic and institutional variables (Tripathi & Prasad, 2009). As a result, marginal and smallholders who depend on agriculture for their livelihood now face unprecedented problems. Though the Indian agricultural production is adequate, productivity is much lower than the world average (Pandey, 2009). Lower productivity may be attributed to a lack of access to modern tools and techniques and fragmentation of land holdings, which is an age-old tradition of the Indian agricultural system (Shetty et al., 2014; Goswami et al., 2017)

The nature of cropping pattern, physiological density, cropping intensity, crop concentration and diversification determines agricultural growth and development in a geographical area. Cropping pattern indicates the sequence or spatio-temporal arrangement of different crops cultivated in a piece of land (Thomas et al., 1990; Mahlayeye, 2022). However, agricultural statistics suffer from detailed and real-time information due to various constraints, but considerable geospatial-based efforts supplemented with field surveys have been able to resolve issues to a certain extent.

Extensive research and studies have been carried out at the international level to understand the spatio-temporal agricultural development scenario using various indices (Siebert et al., 2010; Gilbert et al., 2014; Qiu et al., 2017; Beillouin, 2019; Hufnagel et al., 2020; Mahlayeye et al., 2022 and Du et al., 2023). The studies revealed the indices to be an effective tool in deeper understanding the real-time information and cause-effect relationship for agricultural development. This will further enhance agricultural productivity by practising high-value crops with scientific and technological treatment. Existing literature on the Indian scenario emphasises that the nature of the cropping system practised in the limited rural landscape during the 21st century has become unfeasible; therefore, intensive cropping techniques such as multi-cropping and intercropping are necessary for bringing diverse benefits (Birthal et al., 2006; Ghosh, 2011; Balkrishna, 2021; Chand et.al, 2022; Mujtaba et.al, 2022 and Felix and Ramappa, 2023). They further emphasised that irrigation, farm mechanization, technological advancement, infrastructural development and scientific understanding are the essential tools/driving forces for enhancing the agricultural development. Their studies suggest that understanding the cropping pattern and its associated characteristics, such as intensity, concentration, and diversity would further lead to agricultural sustainability for the entire region. Similarly, limited studies have been undertaken in North-East India in general and Assam in particular (Mandal, 2014; Deka et al., 2018; Handique et al., 2022 and Srivastava et al., 2023). Their research has reflected various challenges hindering agricultural growth, such as erratic monsoonal rhythm, lack of technological advancement, inadequate training facilities, disease and pest problems, limited irrigation facilities etc. Besides, a detailed investigation using a set of combined indices to study the cropping pattern that would further exhibit the agricultural framework is yet to be accomplished in this part of the country.

Though most of the watershed ecosystems of North-East India were once rich in agricultural diversity and sustainability, recent decades have witnessed a substantial decline owing to certain physical and socio-economic attributes. The land use pattern of this region has been drastically transformed into a humanised landscape during the recent past. Therefore, it is high time to claim for a comprehensive and detailed assessment of an ecologically fragile Pachnoi watershed in North-East India based on scientific understanding to achieve sustainable agricultural development. Moreover, the present cropping pattern scenario in this region has become a contemporary issue in light of feeding the burgeoning population on the one hand and increasing food production on the other hand.

The findings of the study would help in framing guidelines for stakeholders, policymakers, academicians and land-use planners in determining a better agricultural output in general and to increase the income of smallholders in particular. The study was designed with a set of objectives: i) to understand the agricultural scenario of the study area, focussing on cropping patterns. ii) to measure cropping patterns using several indices mentioned. iii) To determine the agricultural landholding size and crop production.

Results

Agricultural land use pattern

To achieve the purpose of the study, understanding the agricultural land use pattern is crucial. The agricultural land use pattern, as visualized based on satellite image, revealed various categories, viz. cropland, fallow land and tea garden covering 220.84 km^2 (43.28%) of the watershed's total area (Fig. 1). This land extends from the southern margin of the watershed to the foothill zone located near the border between Arunachal Pradesh and Assam. It has been estimated that a large portion of the study area is categorised as fallow land because of the particular season in which the satellite imagery was taken. Usually, this region practises winter paddy, and the harvesting time gets over by December or January. The cropland category is devoted to winter paddy combined with a few other crops, primarily witnessed in the villages of the southern margin located near the Pachnoi river. Additionally, the areal extension of various land use classes is shown in Supplementary Table 1, indicating a detailed investigation of agricultural land use patterns in the study region. 39 sample villages with their respective areas under different land use categories have been specified. For instance, Fata Simalugaon (416.28 ha) represents the highest area under the category of Total Geographical Area (TGA), followed by Narayan Kati Bangali Gaon (321.43 ha) and Palash Basti (320.25 ha) respectively. Similarly, under the category of Non-Agricultural Uses (NAU), Fata Simalugaon (128.26 ha) has the highest area, followed by Labari Gaon (113.14 ha), while a total of 7 sample villages doesn't cover any area under NAU class. Amongst all the categories, the spatial coverage under the net sown area category of respective villages is considered essential as it will further assist in understanding the cropping pattern of the study area. The analysis reveals that 12 villages have more than 90 % of the net sown area followed by 7 villages with net sown area between 50 % to 90 %, and 13 villages with nearly 10 % of net sown area. One of the critical aspects of the agricultural land use category in the study area is the non- existence of net sown area in 7 sample villages.

Endowed by diverse population composition in the study area, the cropping pattern varies from region to region. The rural villages of the study region practice paddy as a dominant crop, wherein three types of paddy such as summer, winter, and autumn, are grown. Paddy cultivation is practised with vegetables, wheat, rape & mustard, and black gram. Among cash crops, jute, cotton and sugarcane are grown in 10 villages as shown in Supplementary Table 2. Winter paddy (*Sali*) is commonly practised in all the villages, while vegetables are primarily grown in the villages like Fata Simalugaon, No. 2 Kacharibhetitop, No.3 Kacharibhetitop and Nalbari. These are located in the active floodplain zone near the Brahmaputra river. Most farmers use Di Ammonium Phosphate (DAP), potash and urea, while vermicomposting has been adopted in some villages to increase productivity. The villages having irrigation facilities practise summer paddy at the individual level, which is rarely witnessed. Based on irrigation facilities employed, the absence of irrigation facilities has been recorded in 5 villages. Besides, marginal and smallholders adopt local seeds. At the same time, only a few villages use High Yielding Variety (HYV) seeds in lesser quantities through the transplanting method of sowing on soil characteristics ranging from loamy to clayey.

Indicators of cropping pattern

Physiological density

Population dependency on arable land can be measured by physiological density, which is one of the suitable indices of cropping pattern systems (Prabha and Singh, 2015). Higher physiological density indicates heavy population pressure on arable land, thus resulting in low productivity. Spatial distribution of physiological density (village-wise) is illustrated in Supplementary Table 3 and Fig. 2. Based on physiological density, 39 sampled villages have been grouped into four categories viz. low (<5), moderate (5-10), high (10-15) and very high (>15). Table 1 revealed 16 villages under the low category, accounting for 41.02%, followed by 13 villages under moderate (33.33%), 7 (17.94%) and 3 (7.7%) villages within high to very high categories, respectively.

Cropping intensity

The cropping intensity is defined as a ratio between net sown area and gross cropped area. Higher cropping intensity signifies intensive land use for agricultural purposes (Deshmukh & Tanaji, 2017). Table 2 indicated that No.3 Kacharibhetitop exhibits the highest cropping intensity with 186.42 %, followed by Ukubari (174.15 %), Fata Simalugaon (162.70 %) and No.2 Kacharibhetitop (161.85). On the contrary, the lowest cropping intensity has been observed in Gazanga Guri (69.02 %), followed by Osurmari Pathar (77.69%), Raumari Pathar (79.50%) and Praja Basti Gaon (81.75%). Three categories have been identified based on village-wise cropping intensity, viz. (<100 %) low, (100-150%) moderate and (>150%) high. Among 15 villages sampled, 5 fall under low cropping intensity, followed by 6 and 4 villages under medium and high cropping intensity categories, respectively. Fig. 3 depicts the increasing cropping intensity of the villages near the active floodplain zone, assisting occupants to grow more crops with limited inputs due to fertile alluvial soil.

Crop diversification

Crop diversification means the multiple cropping patterns involved in agricultural activities allowing cultivating different crop varieties in the arable land within a specific region (Bradshaw et. al, 2004). The crop diversification pattern in this study has been computed following Bhatia's method (1965). It has been observed that the village-wise crop diversification value ranges from 6.42 to 100, representing high to low crop diversities shown in Table 3. Three categories of crop diversity index have been grouped based on Jasbir Singh's index, viz. (< 15) as high, (15-20) as moderate and (> 20) as low. The low category comprises 9 villages, followed by 3 villages, each in the moderate and high categories, respectively, as illustrated in Fig. 4.

Crop concentration

Crop concentration indicates the spatial density of different crops in a particular region within a given period (Roy, 2014). It is fundamental to understanding the detailed cropping pattern of any area (Bhatia, 1965). Bhatia (1965) applied the Location Quotient (LQ) method to delineate the regional concentration of crops in India. The study incorporates four major crops to calculate the crop concentration revealed from field enquiry: paddy, jute, potato and rape & mustard. The sampled villages comprise a higher dominance of winter paddy as their main crop. The other three crops are also grown widely in those sample villages, but their production is meagre due to various factors. Roumari Pathar, Osurmari Pathar, Amtali Baligaon and Prastabasti are the villages where higher concentrations of winter paddy with indexes of 1.20, 0.92, 0.86 and 0.86, respectively, have been recorded. In contrast, Ukubari (0.47), Fata Simalu (0.49), Moamari (0.54) and Saikia Chuburi No.2 (0.57) have experienced low crop concentration index. The other sample villages viz. Gezenga Guri, Gerujuli, Hugrajuli, Saikia Chuburi, Nalbari, Kacharibhetitop No.1 and No.2 have been ranked under the medium category shown in Table 4. Similarly, Saikia Chuburi, Gerujuli, Gezenga Guri and Amtal Baligaon have higher jute concentrations while potato is highly concentrated in Gezenga Guri, Hugrajuli and Amtal Baligaon. Gerujuli ranks (2.35) highest in the case of Rape & Mustard, followed by Hugrajuli (1.76) and Gezenga Guri (1.26).

Land holdings and related aspects

Land use limitations influence the rational use of agricultural land. Land fragmentation is an obstacle to agricultural development (Austin et al., 2012). Land fragmentation is when a single farm or ownership consists of numerous spatially separated plots (Bentley, 1987). Since paddy has been raised as a principal crop, the area under paddy cultivation and their production plays a significant role in framing their livelihood condition.

Based on occupational patterns and available crop types, 6 villages have been chosen to assess the average land holding size and other aspects. Supplementary Table 4 shows the average size of total land holdings estimated from 0.71 to 3.45 hectares of the sampled villages. Roumari Pathar witnessed the highest average land holding size with 3.45 ha, followed by 3.3 ha in Ukubari and 1.65 ha in Saikia Chuburi. In contrast, the lowest average landholding has been owned by Kacharibhetitop No 2. Most villages have an average family size of 5 members, while Gerujuli and No.2 Kacharibhetitop consist of 6 members. Roumari Pathar, Saikia Chuburi No.2, Ukubari and Kacharibhetitop No.2 have higher cultivators (more than 80 %), whereas Saikia Chuburi and Gerujuli witnessed higher agricultural labourers under the working population group. Monoculture has been practiced in Gerujuli, Sakia Chuburi, Saikia Chuburi No. 2 villages, while Ukubari and Roumari Pathar supports double cropping, and Kacharibhetitop No. 2 practices multiple cropping systems due to occupants of diverse demographic composition.

Agricultural land holdings of sampled households

Agricultural land holding size at the household level considering 20% from each 6 sampled villages has been evaluated. Table 8 shows that 74.19 % of the total sample households of Kacharibhetitop No. 2 bears an agricultural land holding size of less than 0.67 hectares, followed by 50 % in Gerujuli, 36.46 % in Saikia Chuburi and 31.11 % in Saikia Chuburi No.2. The category of 0.67 – 2.01 hectare has been witnessed by 48.89 % households of Saikia Chuburi No.2 followed by 36.36 % of Gerujuli, 33.97 % by Saikia Chuburi and 33.33 % by Ukubari. Roumari Pathar is the only village where 83.33 % of the households among the samples have more than 2.01 hectares under agricultural land holding represented in Table 5.

Crop Production and Estimation

Based on field investigation, it has been estimated that the average yield production of paddy per hectare of land is around 3000 kilograms. It varies with the types of paddy varieties. Varieties like *Ranjit, Bordhan and Maharaja* offer higher production, while *Aijong, Bora and Joha's output* are relatively low. Field observation revealed *Ranjit and Bordhan* as common varieties grown in all villages. Table 6 represents village-wise total crop area, average yield and total yield estimated based on the primary survey done during November 2021. It has been observed that Kacharibhetitop No.2 has the highest percentage (77.63 %) of the area under crop, followed by Gerujuli with 72.02 %, Saikia Chuburi (38.98 %), Ukubari (32.60%), Roumari Pathar (31.04 %) and Saikia Chuburi No. 2 (28.66 %) respectively. The average yield of winter paddy in the sample villages ranges from 8.16 kg/ 25 m^2 in Roumari Pathar to 10.16 kg/25 m^2 in Kacharibhetitop No.2. Similarly, because of the higher percentage of land under crop, Kacharibhetitop No.2 ranks top in total yield with 33442.65 kg followed by Saikia Chuburi No.2, Ukubari, Saikia Chuburi and Gerujuli respectively.

Discussion

Evaluating the mentioned indices provides a clear understanding of the prevailing cropping pattern and associated agricultural characteristics in the study area. The results revealed that the region exhibits a diverse agricultural characteristics, with paddy as the dominant crop. The agricultural land use pattern assessed from the satellite imagery demonstrates that the lower part falling within the political jurisdiction of the government of Assam, located in the Brahmaputra floodplain, is enriched with agricultural

Table 1. Category-wise physiological density of villages.

Physiological Density	Range	Number of Villages	%
Less than 5	Low	16	41.02
5-10	Moderate	13	33.33
10-15	High	7	17.94
More than 15	Very high	3	7.7

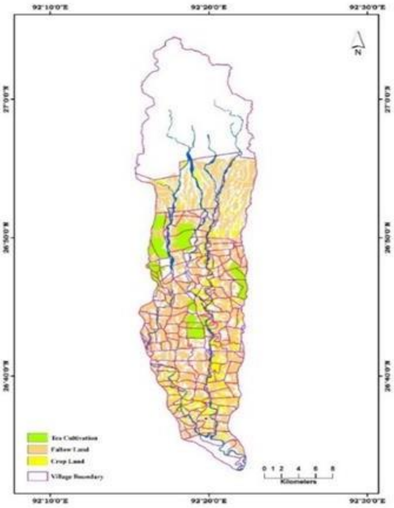

Fig 1. Agricultural land use pattern.

Table 2. Cropping intensity in sampled villages.

Sl No.	Village Name	Net sown area (Ha.)	Winter paddy (Ha.)	Summer paddy (Ha.)	Autumn paddy (Ha.)	Other crops (Ha.)	Total cropped area (Ha.)	Cropping intensity (%)
1	Amtal Bali Gaon	83.23	66.05	8.14	2.46	29.65	106.3	127.72
2	Gazanga Guri	83.77	32.25		4.25	21.32	57.82	69.02
3	Gerujuli Gaon	83.88	54.79	5.06	0	46.65	106.5	126.97
4	Praja Basti Gaon	50.52	22.32	7.33	0	11.65	41.3	81.75
5	Raumari Pathar	10.39	8.26	0	0	0	8.26	79.50
6	Hugrajuli Gaon	91.34	53.68	3.26	0	42.32	99.26	108.67
7	Osurmari Pathar	66.15	36.19	2.98	0	12.22	51.39	77.69
8	Saikia Chuburi	75.05	64.71	0	1.26	36.25	102.22	136.20
9	Saikia Chuburi No.2	3.31	3.31	0	0	0	3.31	100.14
10	Mowamari	90.00	68.56	8.63	0	9.22	86.41	96.01
11	Ukubari	11.09	8.96	4.69	0	5.66	19.31	174.15
12	Fata Simalugaon	54.14	43.21	23.32	0	21.56	88.09	162.70
13	No.2 Kacharibhetitop	93.07	80.52	32.26	0	37.85	150.63	161.85
14	No.3 Kacharibhetitop	95.06	86.36	49.63	0	41.22	177.21	186.42
15	Nalbari	96.52	66.23	32.98	0	29.56	128.77	133.41

Source: Field Survey (2020-22)

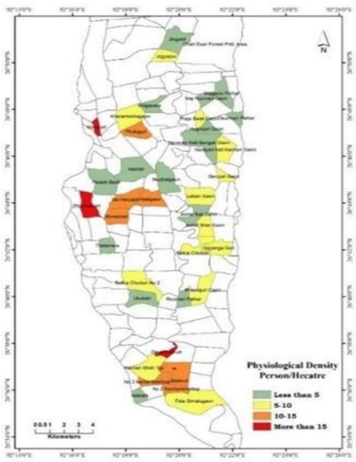

Fig 2. Physiological density.

Table 3. Crop diversification in sampled villages.

Sl No.	Village Name	Crop diversity
1	Amtal Bali Gaon	15.87
2	Gazanga Guri	6.42
3	Gerujuli Gaon	7.26
4	Praja Basti Gaon	11.04
5	Raumari Pathar	79.50
6	Hugrajuli Gaon	8.40
7	Osurmari Pathar	9.12
8	Saikia Chuburi	12.32
9	Saikia Chuburi No.2	100.14
10	Mowamari	19.04
11	Ukubari	26.94
12	Fata Simalugaon	13.30
13	No.2 Kacharibhetitop	14.42
14	No.3 Kacharibhetitop	15.14
15	Nalbari	11.44

Source: Computed from the secondary data and field survey (2020-22)

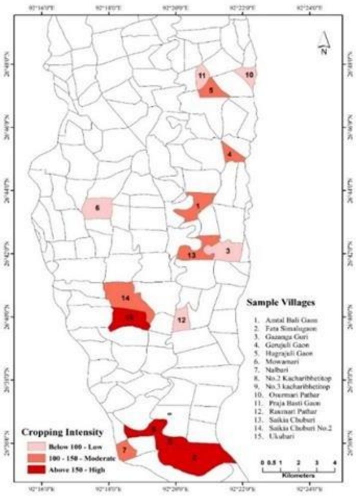

Fig 3. Cropping intensity at village level.

Table 4. Crop concentration in sampled villages.

Sl No.	Village	Winter paddy	Jute	Potato	Rape seed & Mustard
1	Amtal baligaon	0.86	4.43	2.56	0.80
2	Gezenga Guri	0.76	4.76	3.28	1.26
3	Gerujuli	0.68	5.25	2.03	2.35
4	Prajabasti	0.86	3.38	2.38	1.07
5	Roumari Pathr	1.20	0	0	0
6	Hugrajuli	0.71	4.49	3.25	1.76
7	Osurmari Pathar	0.92	2.74	1.91	0.96
8	Saikia Chuburi	0.78	7.65	2.19	1.07
9	Saikia Chuburi No.2	0.57	0	0	0
10	Moamari	0.54	0	0.32	0.32
11	Ukubari	0.47	0	1.06	1.20
12	Fata Simalugaon	0.49	0	0.74	0.34
13	Kacharibhetitop No.2	0.60	0.58	1.56	0
14	Kacharibhetitop No.3	0.61	0.66	1.03	0
15	Nalbari	0.61	0.60	1.33	0

Source: Field Survey (2020-22)

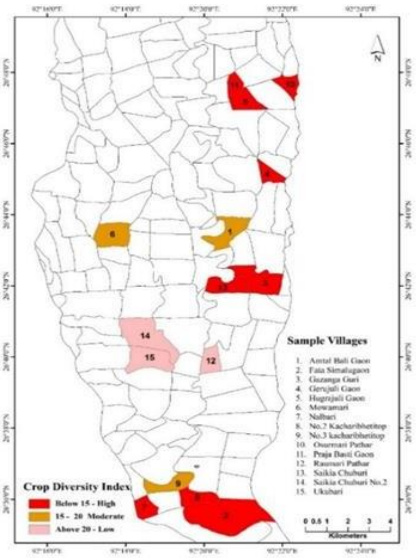

Fig. 4 Crop diversity at village level

Table 5. Agricultural land holding size of sampled households under selected villages.

Samples villages		Landholding Size (in Hectare)		
		Less than 0.67	0.67-2.01	More than 2.01
Gerujuli	No. of Household	11	8	3
	%	50	36.36	13.64
Saikia Chuburi	No. of Household	8	7	6
	%	36.46	33.97	29.57
Roumari Pathar	No. of Household	0	1	5
	%	0	16.67	83.33
Saikia Chuburi No.2	No. of Household	14	22	9
	%	31.11	48.89	20
Ukubari	No. of Household	1	4	7
	%	8.33	33.33	58.34
Kacharibhetitop No 2	No. of Household	46	12	4
	%	74.19	19.35	6.46

Source: Field Survey (2020-22)

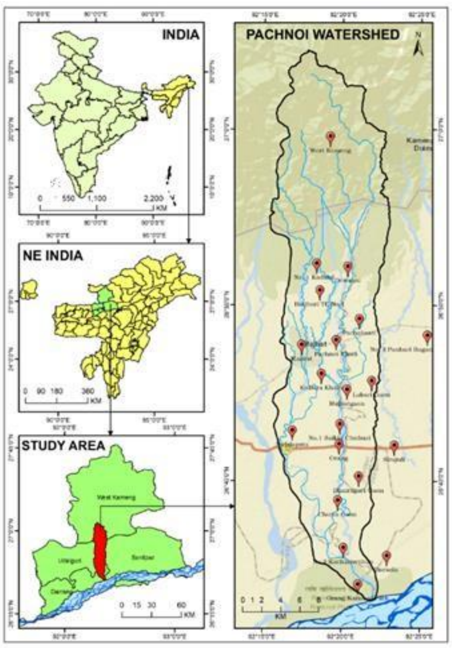

Fig 5. The study area.

belts. The present research has witnessed new insights into agricultural characteristics of this region, viz. total absence and decline of net sown area in many villages, high crop diversification, intensity and concentration in few villages of southern part having low per capita arable land, less variety of crops with low intensity and concentration in the central part having high per capita arable land etc. The field surveys revealed the prevalent occupation shift from farm to non-farm activities in the study region. The factors responsible for the region's impoverished and local variation of agricultural characteristics are the absence of irrigation facilities, institutional credit constraints, traditional farming practices, flood, bank erosion and lack of ready market facilities. These similar conditions and related factors have been recognized as crucial in numerous recent studies in this region by Sharma (2012), Mandal (2014), Baruah et.al, (2020); Handique et al., (2022) and Paria et.al, (2022). Field investigations also indicate that the occupants of the study area shifted their occupation from farm to non-farm activities, currently serving as small tea growers, daily wage labourers, and quarry workers. The women folks have also are engaged in Self Help Groups (SHGs) in order to support better living standards. The low productivity and little gain from the agricultural sector have driven the occupants to change their mode of subsistence, that have also been examined by Mandal et al., (2013) Seitinthang (2014) and Misra et.al, (2023) in their studies. Hence, addressing the mentioned causative factors supplemented by effective strategies would enhance the development of the agricultural sector in this region.

Materials and Methods

Overview of the study area

Pachnoi watershed is a remarkable northern unit of the mighty Brahmaputra river system. Geographically, the region extends between 26° 33′11″ N to 27°04′30″ N latitudes and 92°15′21″ E to 92°23′02″ E longitudes, covering a total area of 504.58 km^2 (Fig. 5). The northern portion falls partly in the West Kameng district of Arunachal Pradesh, while the central and lower part falls partially in three districts, viz. Sonitpur, Udalguri and Darrang of Assam. The region possesses a substantial regional variation in both physical and socio-economic characteristics. The region's topography slopes gradually from north to south, characterized by undulating hills, gentle slopes, low-lying plains, and an elevation ranging from 58 to 2830 metres. The northern part of the watershed is devoid of human population due to physical constraint, while the central and southern regions are comprised of high population density with frequent alteration in land use pattern.

Climatologically, the region receives an average annual rainfall of 1965.5 mm, with maximum rainfall witnessed in the northern part amounting to 2988.2 mm. and minimum rainfall is 1484.32 mm in the central and southern parts of the watershed. The average monthly temperature stands at 26.61°C, while the northern and rest part of the region experiences about 23.02°C and 28.65°C, respectively. The soils of the region are more or less heterogenous in nature comprising soil textures ranging from loamy to gravelly sand and silt. The plain area is dominated by older and newer alluvium deposits**.** The study area comprises 162 revenue villages, of which 158 are located in the plains of Assam and 4 villages are situated in the hills of West Kameng district in Arunachal Pradesh. As per the government census report, the study area comprises 27,827 households sheltering about 1,39,847 populations. Of this, the rural population constitutes 97.41%, wherein their economy is predominantly governed by agriculture.

Data collection and sample survey

The study has been carried out based on primary and relevant secondary data. Secondary information on population characteristics, district and village-level agricultural statistics have been collected from the Directorate of Economics and Statistics, Govt. of Assam and the Census Report. These databases have been employed to understand the agricultural land use scenario, cropping intensity, physiological density, crop concentration and diversity. In addition to that, multispectral satellite data (Landsat OLI 8) having spatial resolution of 30 m have been used to visualise the extension of agricultural fields in the study area. Primary data have been found to be essential and most reliable for the measurement of various indices. Extensive field surveys during the period 2020-22 using objective-specific semi-structured questionnaires for understanding the overall agricultural framework existing in the region. A multi-stage random sampling technique have been applied to collect primary databases from the village (macro) to the household (micro) level. During the first stage, 39 villages (25%) were selected as samples based on specific criteria, viz. physiographic condition, slope nature, nearness to the river and population composition.

In the second stage, out of 39 villages, 15 villages (38%) have been resampled purposively based on having higher area coverage under the net sown area category amongst all agricultural land use types. The primary survey was conducted with the district government officials of district agricultural offices in these villages. Further, to know the nature of the interplay between agricultural development and the livelihood of the rural people, during the third stage, 6 (40%) out of the chosen 15 sampled villages were again resampled. The following villages, namely Gerujuli, Saikia Chuburi and Roumari Pathar, Saikia Chuburi No 2 and Ukubari and Kacharibhetitop No. 2, have been selected for this purpose. Selection has been made based on their occupational pattern and crop types. In the final stage, a sample of 20 % of the households from each 6 resampled villages has been considered using a simple random sampling method to estimate agricultural land holdings and crop production. Hence, the data collected through various sources have been tabulated and processed using statistical tools and techniques.

Measurement Indices

The following indices were used to analyse the primary and secondary data collected at different stages to highlight the status of agriculture in the region.

The indices are physiological density, crop diversification, crop intensity, and crop concentration, with their formulae shown below. For understanding the population pressure on arable land, physiological density is applied wherein,

a) Physiological Density = $\frac{Total\ number\ of\ population}{area\ of\ arable\ land}$

Crop diversification is used to identify the spatial patterns of various crops cultivated in arable land, and for this purpose, Bhatia's method has been adopted.

b) Crop Diversification = $\frac{Percentage\ of\ sown\ area\ under\ 'x'\ crops}{Number\ of\ 'x'\ crops}$

wherein 'x' crops indicate crops that individually occupy 10% or more crop to the net sown area in the villages.

c) Crop Intensity is used to identify the number of crops raised in a particular agricultural year on the same field and is expressed as $\frac{Gross\ cropped\ area}{Net\ sown\ area}$ X 100

d) Crop Concentration has been adopted to delineate crop concentration regions by applying minimum inputs and to generate more output from the same piece of land. For this, the Location Quotient index has been used, which is expressed as

$$L.Q. = \frac{Area\ of\ crop\ 'x'\ in\ the\ village}{Area\ of\ all\ crops\ in\ the\ village} \div \frac{Area\ of\ crop\ 'x'\ in\ the\ revenue\ circle}{Area\ of\ all\ crops\ in\ the\ revenue\ circle}$$

Conclusion

The tale of the agricultural scenario in the study region presents a gloomy picture**.** The farmers of the study area have not been exposed to the utmost taste of the green revolution as they still resist the primitive method of agricultural practice attributed to small land holding size. At the present time, it is critical for human society to attain agricultural sustainability to feed the ever-increasing population. The employed indices have reflected the inefficiency of current agricultural pattern in sustaining the lives and livelihood of the indigenous marginal and smallholders. Our study suggests agricultural intensification through increasing cropping intensity, practising paddy and diverse commercial and non-food crops using HYV seeds. This may provide a promising opportunity to improve agricultural sustainability in the region. Monitoring agricultural environment at regular intervals and adopting site-specific crop management practice would enable the occupants to resume their previous occupation from non- farm to farm-based livelihood. Furthermore, it will aid agronomists, policymakers, stakeholders, and researchers in improving agricultural productivity and efficiency in the long run. Henceforth, this research will serve as a baseline for adopting an integrated watershed management programme (IWMP) with scientific land use planning to gain a sustainable agricultural landscape within the watershed ecosystem.

Conflicts of Interest

As a corresponding author, I do hereby justify that there is no conflict of interest.

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