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Assessing Agricultural Sustainability And Environmental Impacts: A Case Study Of Crop Diversification In Tenga River Basin, West Kameng District, Arunachal Pradesh

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ABSTRACT
Crop diversification is crucial for the agricultural development of any region, as it involves allocating acreage among various crops. This study investigates cropping intensity and patterns in the Tenga River Basin of West Kameng District, Arunachal Pradesh, utilizing primary data collected from 361 farmers through simple random sampling. Two indices, namely the Simpson Index and the Index of Diversification towards High Value Crops (DHVC), are employed to assess the level of crop diversification. The research identifies significant changes in cropping intensity between 2014 and 2024, ranging from 116.94% to 145.49%, with the most substantial increase observed in Rupa Circle from 118.04% to 154.05%. The findings, based on the Simpson Index and DHVC, highlight substantial diversification toward high-value cash crops in the central part of the study area, encompassing Shergaon, Rupa, Bomdila, and Singchung Circles, resulting in increased income for farmers. However, the altered cropping patterns have led to adverse environmental consequences, such as declining soil fertility, forest cover loss and water quality deterioration, posing threats to fish habitats and impacting farmers' health. The study underscores the need for a comprehensive policy that addresses soil fertility management, agricultural diversification, the reinforcement of extension services and the promotion of agritourism to mitigate these challenges.
Keywords: *Crop diversification, Cropping Intensity, Simpson Index, Index of D_{HVC}, Tenga River, Agritourism*

INTRODUCTION

Agriculture is a dominant form of land management globally (**Power, 2010**) which involves production of foods and grains through farming (**Balasubramaniam, 2011**). In its broadest sense, 'agriculture' encompasses a variety of activities that includes not only the domestication of plants and animals useful to man but also many of the operations involved in marketing them. Agriculture has been a fundamental aspect of human societies and economies, intricately connected to the development of human civilization. It has played a pivotal role in enabling communities to establish settled living conditions, representing a crucial milestone in the progress of humanity.

In developing countries like India, agriculture serves a dual purpose, contributing significantly to the economy while also shaping the societal fabric. The 1960s marked the inception of the Green Revolution in India, characterized by the adoption of high-yielding crop varieties, chemical inputs and mechanization, resulting in notable improvements in crop production. However, many of the studies underscore the impact of these advancements, revealing an over-exploitation of natural resources.In the context of Tenga River Basin of West Kameng District in Arunachal Pradesh, there was a paradigm shift in cropping pattern particularly after 1996. The cultivation of cash crops has become a predominant agricultural practice over the past two and a half decades. The shift towards commercial agriculture has led to an expansion in cultivated areas and increased crop productivity. Subsequently, there has been a heightened reliance on chemical fertilizers and pesticides to sustain elevated agricultural outputs. The economic upliftment resulting from agricultural development in the region is undeniable, but it comes with serious repercussions on the quality of the natural environment and the economic structure of the local farming communities. Concerns are raised about the impact of unsustainable agricultural practices on the natural environment and the economic structure of local farming communities. Hence, the present study was undertaken with the objectives to analyze the present status of agricultural land use dynamics in terms of cropping intensity, cropping pattern, crop-combination, crop diversification and production and to study the effect of agricultural development on environment of the study area.The present study assumes an important place as the region has not been studied in depth by any researcher from agricultural and socio-economic point of view. Apart from trying to ascertain various environmental problems faced by agricultural community of this region, the study tries to seek solution to these problems. As a whole, the present study draws attention of the native communities towards adopting sustainable agricultural practices. The results and inferences drawn in the study will prove beneficial to Government Agencies in formulating agricultural plans, policies and developmental schemes and projects.

Study Area Description

The Tenga River Basin, situated in the Central part of West Kameng District in Arunachal Pradesh, has been chosen for the current study. Its geographical coordinates range from 27°02'32" N to 27°21'16" N latitudes and 92°02'16" E to 92°44'48" E longitudes, covering an expanse of approximately 957.94 sq. km. This area constitutes 12.84% of the total district area and features an elongated shape extending from west to east. The topography exhibits diverse landscapes, ranging from an altitude of 523 metres downstream of the Tenga River in the east to 4,099 metres in its upper reaches towards the west, averaging at 2,306 meters above mean sea level **(Megeji, et al., 2020)**. The region experiences an annual average rainfall of 1,704.8 mm, with temperatures ranging from -3.0°C (minimum) to 31°C (maximum). Encompassing significant villages across seven administrative Circles—Dirang, Kalaktang, Shergaon, Rupa, Bomdila, Singchung, and Jamiri—the area is home to the Monpa, Shertukpen, Bugun and Aka tribes. As of the 2011 Census, the study area's population stands at 35,877 persons comprising 20,375 males and 15,502 females. Agriculture serves as the primary economic activity, engaging 27.37% of the workforce, including cultivators (22.88%) and agricultural laborers (4.49%) **(Census, 2011)**.

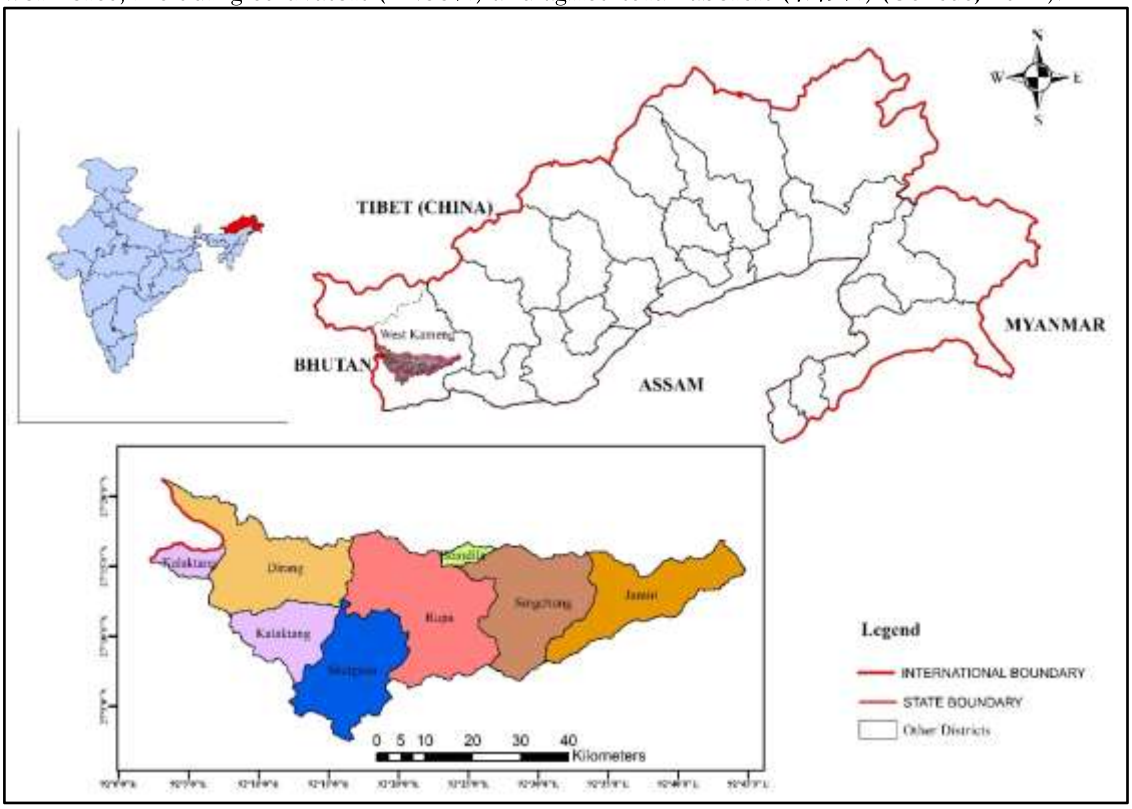

Fig. No. 1: Location Map of Study Area ***Source***: Census of India, 2011.

Objectives

The present study was carried out with the aim to fulfill following two objectives:

1. To analyze present status of agricultural land use dynamics in terms of cropping intensity, cropping pattern and diversity in the study area.
2. To discuss the effects of agricultural development on environment.

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DATABASE

For the purpose of the present study both primary and secondary sources of data were used.

Primary Sources: Primary data has been collected through intensive fieldwork using pre-structured schedules and personal observations at ground level.

Secondary Sources: All the required secondary data for present study were collected from the Government Offices. District Census Handbook Part XII-A and XII-B published by the Directorate of Economics and Statistics, Itanagar, Arunachal Pradesh was used to derive data on population characteristics and occupation structure of the study area.

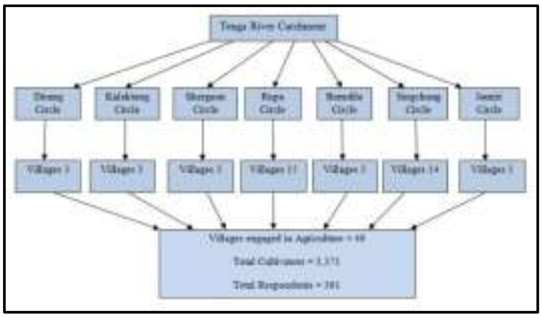
METHODOLOGY

Sample Design

To fulfill the objectives of the present study the primary data pertaining to socio-economic characteristics and agricultural practices of the farmers/cultivators was collected on the basis of random sampling technique. The Figure No. 2 shows the sampling methodology and number of villages covered from each Circle and the Figure No. 3 shows the location of the sampled villages. 361 farmers out of 3,371 recorded in the study area were interviewed using pre-structured schedules. The sample size conforms to 95 percent confidence level with an error margin of 4.78 percent.

Analytical tools

The data collected from the sample farmers using pre-structured schedule were analyzed and estimated with certain statistical techniques like average, cropping intensity, cropping pattern, crop combination and represented in tables and diagrams. Personal observation supplemented by responses to open ended questions elicited more detailed information and understanding to draw inferences.



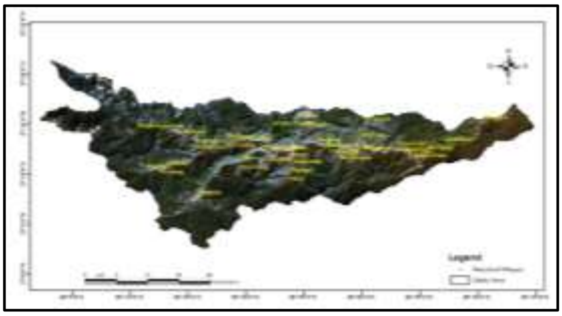


Fig. No. 2: Flow Chart of Sampling Methodology **Fig. No. 3: Location of Sample Villages** **Source**: GPS points obtained during Field Survey, 2024

RESULTS

Agricultural Land use Dynamics

Agricultural land use dynamics in terms of cropping intensity, cropping pattern, crop-combination, crop diversification and production reflect the socio-economic condition of the farmers of a particular region. Therefore, an attempt is made to examine spatio-temporal differences in agricultural land use dynamics on the basis of primary data.

Cropping Intensity

Food and Agricultural Organization (FAO) of the World, United Nations defines Cropping Intensity to be the fraction of the arable area that is harvested. It refers to a measure to express the use of land during an agricultural year.

The most common method of its measurement is (**Mohammad & Rai, 2014**):

$$C.I = \frac{GCA}{NSA} X100$$

Where,

C.I = Intensity of Cropping or Cropping Intensity

GCA = Gross Cropped Area
NSA = Net Sown Area

Due to the scarcity of level land, which is primarily available along the banks of the Tenga River and its main tributaries, agricultural activities have expanded to areas where favorable terrain conditions exist, often involving the clearing of rich forest cover. The average operational landholding for farmers in the study area is approximately 2,757.07 square meters (sq. m) or 0.68 acres. Consequently, the intensity of cropping is notably high in the study area due to the limited agricultural land at the disposal of the farmers. The current cropping intensity in the study area is recorded at 145.49 percent, surpassing the district average of 131.03 percent (Directorate of Economics and Statistics, 2012). However, significant spatio-temporal variations exist in cropping intensity within the study area. In 2014-15, it was around 116.94 percent, increasing to nearly 145.49 percent in 2024-25, marking a growth of 28.54 percent. Circles such as Rupa, Bomdila, and Singchung exhibit cropping intensities higher than that of the district, recording 154.05 percent, 151.77 percent, and 147.68 percent, respectively, in the central part of the study area.

	2014-15			**2024-25**			%
Circles	**N.S. A.* (in m²)**	**G.C.A.** (in m²)**	**C.I.*** (in percent)**	**N.S. A.* (in m²)**	**G.C.A.** (in m²)**	**C.I.*** (in percent)**	**Change in C.I**
Dirang	21896	24066	109.91	30730	37628	122.45	12.54
Kalaktang	16384	18846	115.03	26457	35805	135.33	20.31
Shergaon	95357	107837	113.09	174954	227210	129.87	16.78
Rupa	192708	227474	118.04	447068	688724	154.05	36.01
Bomdila	31245	38920	124.56	41219	62558	151.77	27.21
Singchung	25972	31478	121.2	87036	128537	147.68	26.48
Jamiri	25005	29167	116.64	26364	32650	123.84	7.2
Overall	408567	477788	116.94	833828	1213112	145.49	28.54

Table No. 1: Circle-wise Cropping Intensity*Net * *Net Sown Area, **Gross Cropped Area and ***Cropping Intensity *Source*: Field Survey, 2024

Cropping Pattern

Cropping pattern refers to the combination and number of crops grown in the area along with the agricultural characteristics. It is the proportion of area under various crops at a point of time. Variety of crops is grown in study area but the percentage share of some of the principal crops is given in Figure No. 3 and circle-wise percentage area under principal crops is given in Table No. 2. The production data of individual crops at district level was obtained from the Office of the Deputy Director of Agriculture, Bomdila, Government of Arunachal Pradesh for the District corresponding to the year 2024 as the production data was not available for circle level.

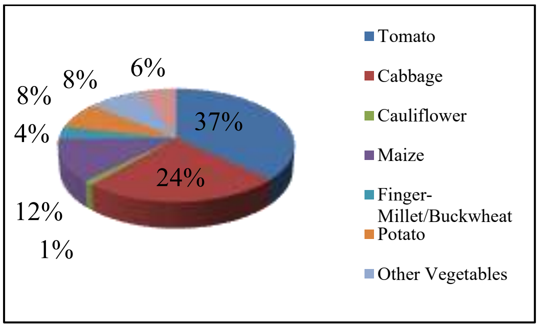


Figure No. 3: Percentage Area under Principal Crops in Study Area **Source:**Field Survey, 2024

Circles	Tomato	Cabbage	Cauliflower	Maize	Finger-Millet & Buckwheat	Potato	O. Vegetables	H. Crops	Overall
Dirang	32.44	13.99	0	28.12	20.78	0	4.67	0	100
Kalaktang	36.31	22.2	0.28	12.81	3.45	16.6	7.34	0.97	100
Shergaon	44.22	15.36	0	7.27	0.76	12.75	3.4	16.24	100
Rupa	69.83	14.69	0.95	2.8	0	1.52	3.78	6.42	100
Bomdila	25.6	48.48	0.64	1.12	0	13.01	9.22	1.93	100
Singchung	28.87	56.27	6.53	0.86	0	4.38	2.06	1.02	100
Jamiri	20.99	0.41	0	33.39	0	4.96	26.2	14.04	100

Table No. 2: Circle-wise Distribution of Principal Crops (% Share to Gross Cropped Area) **Source:** Field Survey, 2024

Crops	Production (in MT)
Tomato	5210.05
Cabbage	3060
Cauliflower	116
Maize	4785.5
Millet and Buckwheat	1358.89
Potato	3299.4
Other Vegetables* (Chilly,Pea etc.)	2738

Table No. 3: Crop Production in respect of West Kameng District, 2024 **Source**: Office of the Deputy Director of Agriculture, Bomdila

Tomato

Tomato (*Solanum lycopersicum*), a popular vegetable crop though botanically classified as fruit crop, has become the predominant crop in the study area. The cultivation of tomato plants has consistently expanded in the region since its introduction in the late 1990s in Rupa Circle by *Shri Rinchin Dorjee Thongdok*, a forward-thinking farmer, with technical assistance from the Field Staffs/Officials of the Department of Agriculture, Rupa Sub-Division, Government of Arunachal Pradesh. Various tomato varieties, including *Cheeranjavi*, *Rocky*, *Avinash*, *Namdhari*, *Aditi*, and *Raja* are now widely cultivated in the study area for commercial purposes.

Although specific data on tomato acreage is unavailable for the preceding two decades, the estimated percentage share of tomato in the Gross Cropped Area for the year 2014-15 is 36.89 percent, based on a field survey. In the year 2024-25, tomato production in West Kameng District was estimated at 5,210.05 metric tonnes (Table No. 3). It is reasonably assumed that the majority of this production originates from the study area, as other parts of the district have not yet embraced large-scale tomato cultivation.

Cabbage

Cabbage (*Brassica oleracea var capitata*) holds significant agricultural importance in the study area due to its short growing season. In the year 2024, the district achieved a cabbage production of 3,060 metric tonnes, with the study area contributing substantially to this total (Table No. 3). The optimal temperature range for cabbage growth is considered to be 15°-21° C. It thrives in soils ranging from sandy to heavy, rich in organic matter, provided with proper irrigation, fertilizers, manure, and the application of chemical pesticides and insecticides. The acreage devoted to cabbage cultivation accounts for 24.49 percent of the Gross Cropped Area in the study area. Among the Circles, Singchung Circle leads with the highest share of Gross Cropped Area dedicated to cabbage cultivation at 56.27 percent, followed by Bomdila Circle at 48.48 percent. Notably, cabbage cultivation in these Circles is primarily undertaken by the non-native population.

Cauliflower

Cauliflower (*Brassica oleracea*) is one of the several species of vegetables grown in the study area. The total cauliflower production recorded in the District is 116 metric tonnes in the year 2024 (Table No. 3). Only percentage share of 1.20 of the Gross Cropped Area is devoted to its cultivation in the study area. Other than Singchung Circle, where it occupies 6.53 percent of Gross Cropped Area, this vegetable crop is not given much preference over other crops as it is seen that it occupies area below 1 percent of Gross Cropped Area in all the Circles.

Maize

Maize (*Zea mays L*) stands as a significant cereal crop in the region. Before the introduction of cash crops such as tomato, cabbage, and horticultural crops, maize held prominence as one of the main crops for the local inhabitants. Indigenous communities were engaged in shifting cultivation on hill-slopes, where maize was the primary crop, covering the largest area. However, the areal coverage of maize has significantly dwindled, now constituting only 12.34 percent of the Gross Cropped Area. This decline is attributed to its diminished market value and its substitution as a food source by readily available rice in the market and cooperative shops. Large-scale maize cultivation is prevalent outside the study area within the district, contributing to an annual production of 4,785.5 metric tonnes (Table No. 3).

Finger Millet, Barley and Buckwheat (Other Cereals)

Finger Millet (*Eleusine coracana L.*), Barley (*Hordeum vulgare*), and Buckwheat (Fagopyrum esculentum) are cereals cultivated in the study area, collectively representing 4 percent of the Gross Cropped Area. Within the Dirang Circle, specifically in Khellong, Bamrok, and Mandalaphudung villages, these cereals contribute significantly, accounting for 20.78 percent of the Gross Cropped Area. These grains play a crucial role for the residents of this Circle, serving both as culinary staples and fodder for livestock. Nevertheless, due to economic considerations, farmers are gradually shifting away from cultivating these cereals, with cash crops like tomato and cabbage taking precedence. The total annual production of these cereals in the district is estimated at 1,358 metric tonnes, with the majority of the contribution coming from areas outside the study zone.

Potato

Potato (*Solanum tuberosum)* is an important root vegetable grown in the study area as a *Rabi* season crop. The agricultural fields after the harvesting of tomato fruits are left fallow for about a month before preparing them for the sowing of *seed potatoes* during the month of December-January. It is usually harvested in April-May month. The percentage share of potato cultivation to the Gross Cropped Area is estimated to be 7.60 percent in the study area with three important villages of Kalaktang Circle (16.60 percent) in upper Basin area leading in terms of percentage share devoted to its cultivation amongst all the Circles. Potato is grown by the farmers of these Circles to meet up its demand as an important vegetable item in nearby markets. It recorded an annual production of 3,299 metric tonnes in the district during the year 2024.

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Other Vegetables

The farmers of the study area also grow varieties of other vegetables including *green leafy vegetables, pumpkin, chilly* and pulses such as *beans*, *peas and soybean*. These vegetables are also sold in small scale in the nearby markets. The spatial distribution of percentage share of these vegetables to the Gross Cropped Area is 8.16 percent in the study area.

Horticultural Crops

The Study area is also famous for the variety of horticultural products such as *kiwi*, *walnuts*, *apple* and *orange*. The areal strength of horticultural crops in percentage share of Gross Cropped Area is estimated to be 5.32 percent with Shergaon Circle leading in terms of percentage share with 16.24 percent of Gross Cropped Area under horticultural crops. Horti-products of Shergaon such as different varieties of *apple, kiwi, walnut, chestnut, plum, peach* and *cherry* fetch good price in the markets of Assam. In Jamiri Circle (14.04 percent) also, some of the farmers are growing *orange* for commercial purposes.

Crop Combinational Analysis

Individual crops may be studied in Agricultural Geography for their own sake. However, the study of crop combination regions constitutes an important aspect of agricultural geography as it provides a good basis for agricultural regionalization.

Crop-combinations were identified on the basis of percentage strength of the crops before the evolution of statistical techniques. In this study, Doi's Modified Minimum Deviation Method which is simple and easy to work with, has been used.

Crop Combination Regions

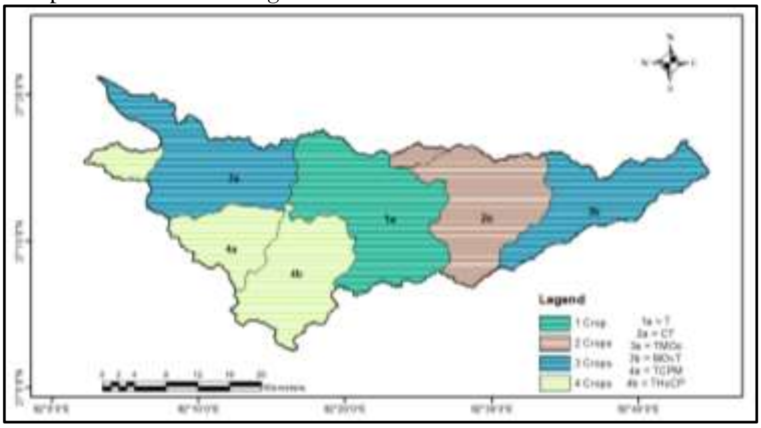

Fig. No. 5: Circle-wise Crop Combination Source: Field Survey, 2024

1. Monoculture Region (1a =T): It is only in Rupa Circle that monoculture is practiced wherein tomato dominates all other crops due to its high remunerative value. The practice of monoculture is due to the impact of commercial agriculture as growing tomato in this circle gives the highest return. The cultivation of tomato is facilitated by the favourable agro-climatic conditions.

2. Two Crop-Combination Region (2a=CT): In Bomdila and Singchung Circles two crops i.e. cabbage and tomato have come in combination. This practice of growing cabbage and tomato in combination is favoured by the suitable geo-environmental conditions enabling the farmers to earn good return.

3. Three Crop-Combination Region (3a=TMOc): It is in Dirang Circle that 3-crop combination of tomato, maize and other cereals such as finger millet and buckwheat is found. This combination is an indication that as an inducement of commercialization of agriculture tomato cultivation is gaining importance. The farmers still continue to grow maize and other cereals such as finger millet and buckwheat due to socio-religious consideration as these cereals are consumed as staple food and used in religious functions.

4. Three Crop-Combination Region (3b=MOvT): It is in Jamiri Circle that 3-crop combination of maize (M), other vegetables (Ov) and tomato (T) is found. Maize and other vegetables are grown here widely for self consumption while tomato has been recently introduced for commercial purpose.

5. Four Crop Combination Regions (4a=TCPM): 4 Crop Combination Region of tomato(T), cabbage (C), potato (P) and maize (M), includes the three villages of Morshing, Sanglem and Domkho in Kalaktang Circle. While tomato, cabbage and potato are grown with commercial motive, crop such as maize are grown for self consumption or to be sold during lean season.

6. Four Crop Combination Regions (4b=THcCP): Shergaon Circle including the villages of Shergaon, Jigaon and Musakshing form the region of 4 Crop Combination. Tomato (T), horticultural crops viz. apple, kiwi, persimmon, plum, cherry, chestnut, walnut (Hc), cabbage (C) and potato (P) are the crops grown here for commercial purpose.

Crop Diversification

Crop diversification means rising of a variety of crops involving intensity of competition amongst field crops for arable or cultivable land (**Sharma et al., 2014**). To assess the nature of crop diversification, it is important to calculate the diversification towards High Value Crops or cash crops (**Bhat & Salam, 2016**). Considering the objective of the study, crop diversity index of the study area has been worked out using Bhatia's Diversification Index, Simpson Index and Diversification towards High Value Crops.

Bhatia's Method

Bhatia in 1965 developed a formula based on Gross Cropped Area (GCA) for the measurement of crop diversification. The formula has been expressed as:

$$ICD = \frac{\sum_{i=1}^{n} x_i}{n}$$

Where,

ICD=Index of Crop Diversification

x_i = Percentage of crops to Gross Cropped Area

n = number of crops occupying 10 percent or more of the gross cropped area

However, Singh in 1972 using the same percentage strength of the crop has modified this formula by considering all crops that occupied 5 percent or more of the gross cropped area. In both the cases, the relationship between the crop concentration index and crop diversification is inverse. A high index value shows lesser diversification and increased specialization and a low index value shows higher diversification. Since Bhatia's index is an index of concentration, to avoid the confusion in measuring the diversification, this index was transformed. The method for transformation is 1- (Index Value/100). This avoids confusion in measuring diversification. A higher value of transformed index implies higher diversification and lower value implies lesser diversification (**Bhat & Salam, 2016**).

Simpson's Method

Simpson Index of diversification (SI) was used and it is considered as the most suitable index for measuring dispersion of enterprises in a particular geographical region (**Joshi et al., 2003**). Simpson's index is a measure of horizontal diversification. Horizontal diversification is the increase in the number of crops grown given the economical rationality of this expansion (**Meena et al., 2016**). This index has been worked out using the following formula:

$$\mathbf{ICD} = 1\text{-}\left(\frac{\sum n(n-1)}{N(N-1)}\right)$$

Where,

ICD=Index of Crop Diversification

n=percentage share of individual crops to the gross cropped area

The value of **ICD** in case of **Simpson's Method** ranges between 0 and 1. If there is diversification, the value moves towards 1 and if the estimated value is near 0, it indicates that the region is specialized in growing of particular crops only, implying less diversification.

Diversification towards High Value Crops

Diversification towards high value cash crops may be computed by using the formula given by **Bhat** and **Salam (2016)** which is as follows:

$$D_{HVC} = 1 - (proportion\ of\ area\ under\ subsistence\ crops)$$

Where,

HVC = High Value Crops/ Cash Crops

The Index value ranges from zero to one. A higher value of D_{HVC} with index value implies that more of the area is under high value crops and vice-versa. Using above formulae, the Crop Diversification Indices of the Study Area as a whole and various circles within the study area were calculated (Table No. 4 and 5):

Crops	**Percentage share to the G.C.A (n)**	**n (n-1)**
Tomato	36.89	1323.982
Cabbage	24.49	575.27
Cauliflower	1.2	0.24
Maize	12.34	139.936
Finger-Millet/Buckwheat (Oc)	3.57	9.175
Potato	7.6	50.16
Other Vegetables (Ov)	8.24	59.658
Horticulture	5.8	27.84
Total	**100**	**2186.26**

Table No. 4: Crop Diversification Index of Study Area

Bhatia's CDI = (36.89+24.49+12.34+7.6+8.24+5.8)/6

= 15.89

Transformed Bhatia's CDI = 1- (15.89/100)

= 0.8411

Simpson's Diversity Index = 1- ((2186.26)/100*99)

= 0.779

= 0.78

D_{HVC} = 1-(12.34 + 3.57 + 8.24/100)

= 1- 0.2415

= 0.76

The Crop Diversification Index for the Tenga River Basin, calculated using Bhatia's method with modifications suggested by Singh, is determined to be 15.89. After transformation using the formula 1-(Index Value/100), the resulting value is 0.8411. Additionally, the Crop Diversification Index for the study area, calculated using Simpson's method, is found to be 0.78. Both indices indicate a high level of crop diversification in the study area. The D_{HVC} value, signifying concentration toward the production of High Value crops, is also high at 0.76.

For this study, the results obtained through Simpson's method are considered, as it accounts for the percentage share of all crops, unlike Bhatia's method, which excludes crops occupying less than 5 percent of the gross cropped area. Analyzing the spatial variation in crop diversification and diversification towards high-value crops at the circle level (Table No. 4 and 5), it is observed that Kalaktang Circle exhibits the highest crop diversification with an index of 0.78. The D_{HVC} value of 0.76 suggests a moderate concentration of cash crops such as tomato, cabbage, and potato. Dirang Circle and Shergaon Circle also show high crop diversification with indices of 0.76 and 0.74, respectively. However, the concentration of high-value crops is low in the villages of Dirang Circle (D_{HVC} value of 0.46), while Shergaon Circle has a high concentration (D_{HVC} value of 0.89) of cash crops like tomato, cabbage, horticultural crops and potato.

Jamiri Circle, despite its lesser agricultural significance, has a high Crop Diversification Index of 0.76, with low diversification towards high-value cash crops (D_{HVC} value of 0.40). In circles like Rupa (0.49), Singchung (0.60), and Bomdila (0.68), crop diversification is noted to be low to medium, indicating commercialized agriculture. These circles have high D_{HVC} values of 0.93, 0.90, and 0.97, respectively, suggesting a specialization in growing cash crops such as tomato, cabbage, and horticultural crops. This indicates that the central part of the study area forms a contiguous region specialized in the cultivation of cash crops, with agriculture highly commercialized due to a well-established road transport network.

Crops	**Dirang**	**n (n -1)**	**Kalaktang**	**n (n -1)**	**Shergaon**	**n (n -1)**	**Rupa**	**n (n -1)**	**Bomdila**	**n (n -1)**	**Singchung**	**n (n -1)**	**Jamiri**	**n (n -1)**
Tomato	32.44	1019.82	36.31	1282.26	44.22	1911.17	69.83	4806.14	25.60	629.80	28.87	804.45	20.99	419.745
Cabbage	13.99	181.86	22.2	470.69	15.36	220.49	14.69	201.24	48.48	2301.88	56.27	3110.32	0.41	-0.2426
Cauliflower	0	0	0.28	-0.2	0	0	0.95	-0.05	0.64	-0.23	6.53	36.06	0.00	0
Maize	28.12	762.47	12.81	151.24	7.27	45.54	2.8	5.05	1.12	0.14	0.86	-0.12	33.39	1081.59
Finger-Millet & Buckwheat	20.78	411.02	3.45	8.46	0.76	-0.18	0	0	0.00	0.00	0.00	0.00	0.00	0
Potato	0	0	16.6	258.99	12.75	149.91	1.52	0.79	13.01	156.23	4.38	14.83	4.96	19.6475
O. Vegetables	4.67	17.13	7.34	46.59	3.4	8.15	3.78	10.53	9.22	75.70	2.06	2.19	26.20	660.389
H. Crops	0	0	1	0	16.24	247.65	6.42	34.83	1.93	1.79	1.02	0.03	14.04	183.008
Total	100	2392.31	100	2218.03	100	2582.74	100	5058.54	100.00	3165.30	100.00	3967.75	100.00	2364.13
Bhatia's CDI	23.83		19.05		19.17		30.32		24.08		30.56		23.66	
Transformed Bhatia's CDI	0.76		0.81		0.81		0.7		0.76		0.69		0.76	
Simpson's Diversity Index	0.76		0.78		0.74		0.49		0.68		0.60		0.76	
D_{HVC}	**0.46**		**0.76**		**0.89**		**0.93**		0.90		0.97		0.40	

*n=percentage share of individual crops ***Source:*** Field Survey, 2024.

Table No. 5: Circle-wise Crop Diversification Index of Study Area

Effects

Various problems arising out of agricultural practices in study area were identified and are presented as below:

Soil Health Impact

Farmers in the region extensively apply inorganic fertilizers in granular form to boost crop yields. Prior to each cropping cycle, farmers traditionally use the broadcasting method to apply Nitrogen (N), Phosphorus (P), and Potassium (K) fertilizers, including Di-ammonium Phosphate (DAP), Ammonium Phosphate Sulphate Fertilizers, and urea. According to 29.92 percent of farmers, the indiscriminate use of inorganic fertilizers leads to soil quality deterioration and adversely affects field yields. However, 46.81 percent of farmers deny any decline in soil fertility, while 23.27 percent report being unaware of such changes. The analysis of physico-chemical soil properties in selected agricultural fields by the Office of the District Agriculture, Government of Arunachal Pradesh, aligns with farmers' perceptions, confirming declining soil fertility. The soil pH is found to be moderately (5.6-6) to strongly (5.1-5.5) acidic at all sampled sites. Therefore, conducting time trend analyses of fertilizer use rates in the study area is crucial to validate the concept of 'declining soil fertility' and its associated adverse effects. Creating awareness among farmers and providing on-site training by agricultural experts can contribute to solving this issue to some extent.

Reduction in Fish Catch

The examination of the major ion chemistry of the Tenga River conducted by Sharma and Sarma (2011) reveals that the extensive application of fertilizers and pesticides has a notable impact on the water quality of the Tenga River. This impact is primarily attributed to farmland runoff, given the absence of industrial units in the study area. The discharge of chemical and toxic substances, specifically fertilizers and pesticides, into the Tenga River and its tributaries poses a potential threat to the habitat of fish. Additionally, farmers in the study area have reported a 'reduction in fish catch,' which may be linked to the adverse effects of farmland runoff.

Reduction of Bamboo Forest

The adoption of modern agricultural practices in the study area poses a significant threat to the natural resource base, as it has been observed that the expansion of agricultural lands coincides with a reduction in forest cover. The depletion of bamboo forests in the study area is directly linked to the introduction of high-yielding varieties of tomatoes. Local farmers in the study area construct bamboo trellises, locally known as '*Chaang*' to support the weight of fruiting tomato plants. This process involves erecting wooden support posts (typically straight branches of pine trees) standing 3 to 4 feet above the soil, spaced about 10-12 feet apart along the length, and 3 feet apart along the breadth. Bamboo poles are horizontally tied to connect the support posts along the length, and light bamboo sticks are placed across them, serving as support for the branches of tomato plants. The field survey revealed that the depletion of bamboo in the adjacent forests has made procuring it from other areas a costly affair. To address this issue, farmers may be encouraged to use string trellises, even if it requires more labor, after a thorough evaluation of the associated costs

Health Impact

The present agricultural practices in the study area involve application of exceedingly high quantity of agrochemicals such as pesticides, insecticides, fungicides and herbicides in granular or liquid form. Susceptibility of vegetable crops to insects, pests and diseases due to erratic weather conditions compel the farmers to use agrochemicals indiscriminately. The agrochemicals used by the farmers under the brands such as *Indofil M-45*, *Tatafen, Rogor, Sectin* and *Profex* fall under the categories of *carbamate* (C), *pyrethroid* (PY) and *organophosphate* (OP) respectively. These brands contain *profenofos* (OP), *cypermethrin* (PY), *fenvalerate* (PY), *dimethoate* (OP), *fenamidone* and *mancozeb* (C) which according to World Health Organization (WHO) are moderately to highly hazardous. The adverse effects of exposure to these chemicals include cancers risks and developmental disorders amongst the farmers (**WHO, 2019**).

Majority of farmers (73.13 percent) never use protective equipment because they find it uncomfortable to wear during hot weather seasons despite the reported cases of health hazards after prolonged exposure to the pesticides. In a study by **Foucault et al**. (**2021**) the argument that leukemia as an illness is linked with occupational pesticide exposure was reinforced though several of the cancers that are excessive among farmers appear to be associated with genetic induced immuno-deficiencies (**Filipovich, 1980**). On the condition of anonymity, it was known that there are three farmers suffering from leukemia which may substantiate the adverse effects of prolonged pesticide use in the region. Therefore, epidemiologic investigations among farmers may provide important links between pesticide use and cancer risks.

Impact on Indigenous knowledge and traditional agriculture

During the field study it was observed that the traditional agricultural practices such as the use of wooden-plough drawn by oxen, application of organic manures and composting have almost faded into insignificance as a result of introduction of cash crops. However, efforts should be made to revive indigenous knowledge and traditional practices in agriculture. Non-Governmental Organizations (NGOs) and Self Help Groups (SHGs) can play a leading role to encourage incorporation of traditional knowledge into new technologies for further innovations. Local Governing Bodies across different tribal groups can make a basic starting point by developing the body of indigenous knowledge through extensive research and formally maintaining the record and making traditional knowledge freely available.

CONCLUSION

The analysis of agricultural land use dynamics reveals that the overall cropping intensity in the study area is very high due to limited agricultural land under the possession of farmers. Significant spatio-temporal difference in cropping intensity within the study area has been observed. There is also increase in cropping intensity from 2007-08 to 2024. Further intensification of agriculture in the study area is undesirable as it would lead to deterioration of agricultural land. As revealed from the crop-combination and crop diversification analysis, cropping pattern in the study area has shifted towards the growth of cash crops. Currently, tomato and cabbage together account for more than 60 percent of the gross cropped area. Various indices of crop diversification show study area to be highly diversified towards commercial crops. This is in contradiction to the scenario that was prevalent two decades ago as revealed by the farmers. The present cropping pattern is augmented by agro-climatic conditions that favour the growth of variety of crops across different seasons in some parts of the study area and also motivated by socio-economic characteristics that determine the adoption decision of farmers.

As a result of modern agricultural development the study area is witnessing adverse environmental problems in the form of declining soil fertility, loss of forest cover (**Megeji et al., 2021**), deterioration of water quality threatening fish habitat along with adverse impacts on farmers' health, loss of indigenous knowledge and traditional agriculture. Based on the comprehensive summary of the major findings, the present study proposes a policy involving following components: 1) Development of rural infrastructure to enhance effective delivery of input and output in marketing systems. 2) Soil fertility management by extending soil-health card services to all the farmers. 3) Diversification of agricultural activities towards non-crop agricultural activities such as fish farming. 4) Effective policy on pricing of agricultural produce so that the farmers' receive fair share of income generated from their produce. 5) Strengthening the role of extension services to improve the technical know-how of the farmers with regard to correct application of chemical fertilizers and pesticides. 6) Promotion of Agritourism by incorporating organic farming practices of horticultural crops and tourism development initiatives to ensure sustainable income to the farmers of the study area.

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