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Changing Pattern of Agricultural Productivity in Brahmaputra Valley

Surendra Singh and Bimal Sharma*

I

INTRODUCTION

Agricultural sector is dominant in the economy of the Brahmaputra valley which shares more than 50 per cent to the total gross domestic product and employs about 70 per cent of the workforce in it. In spite of favourable agro-ecological (soil-weather) conditions for agricultural development and growth, the land use trends were being observed as stagnant and steady during the 1970s and 1980s. However, there was a marginal increase in the net sown area (NSA) and crop yield during the mid-1990s when the processes of expansion and intensification in agricultural land use were accelerated under the significant impact of green revolution in this part of the country (Singh and Sharma, 2003). There are many dimensions of viewing intensification in the agricultural practices as studied by Nath (1969), Bhat and Learnmonth (1968), Singh (1974), Bhalla and Tyagi (1989) and Singh (1994) giving regional account of Indian agriculture for its development and planning. Such studies seek and search the weakness of agricultural growth and development processes in its regional context highlighting the areas of weak infrastructure, suitable cropping pattern in relation to existing agro-ecological conditions, the emerging production pattern in its socio-economic setup and the optimal spatial organisation of agricultural land uses. However, it is a fact that agriculture in India is foodgrain dominated and labour intensive because of smaller size of land holdings (Wharton, Jr 1969). Such relevant aspects of agricultural intensification and productivity increase were taken up by way of testing the validity of Boserup's (1965, 1981) study of population-production nexus in agricultural activities. After the use of regression analysis of increasing density of rural population (as independent variable) and crop-intensity (as dependent variable), Das (1984: pp.90-95) concluded that the thesis is valid for the plains of Assam during the 1970s when there was not much use of modern technology in the agricultural practices interpreting that there is about 50 per cent

*Department of Geography, North Eastern Hill University, Shillong - 793 022, Department of Geography, Gauhati University, Guwahati - 781 014, respectively.

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variation in crop-intensification subject to the variation of population pressure in the valley. More or less similar findings are also drawn by Barah (2003) establishing relationship between agricultural productivity and population pressure for the district of Jorhat located in the Upper part and Bhagabati (2000) for the lower parts of Brahmaputra valley. In fact, increasing population pressure in rural areas increases labour intensity in agricultural practices and if there is no record shift of rural labour to non-agricultural sectors, it diminishes the labour productivity in agricultural practices as widely accepted (Bhalla and Alagh, 1979; Singh, 1994, pp.87-99). It is also true for agricultural areas of Manipur and Assam valleys (Singh, 1998, Sharma, 2003). However, crop-yield increase is likely to be possible because either changes in agro-ecological conditions or implementation of new technology schemes initiated by the governmental agencies in the valley (Goswami, 1988 pp.83-96). The effects of ecological and technological production factors may be isolated to use homogeneous agro-ecological zones as base and to observe changes of agricultural productivity within and between them.

The present research, thus, addresses the issue relating to emerging pattern of agricultural productivity in Brahmaputra Valley by analysing its inter- and intra-zonal variations for the causes of such changes.

II

WHAT IS AGRICULTURAL PRODUCTIVITY AND ITS MEASUREMENT?

Reviewing the literature on various aspects of the measurement of agricultural productivity and production of different crops in different agro-ecological conditions and also on their economic importance (the market forces and use of modern technology) as well as social status (family requirements), Kendall (1939) used factor analytic approach and calculated latent roots (or eigen vectors) to assign weights of individual crop-production for the assessment of agricultural productivity patterns which emerged in England during the 1930s. Further, a simple ranking coefficient technique of calculation of agricultural production was used first by Stamp (1960) for 20 countries of the world and later on by Shafi (1960) for the state of Uttar Pradesh, India. Bhatia's (1967) yield-weight method, Singh and Chauhan's (1977) crop-equivalent coefficient method and Bhalla and Tyagi's (1989) method of production aggregation in terms of money are noticeable measurements of productivity for showing diversification in agricultural production patterns emerging in India. If total crop-production produced by a piece of land is a product of many factors like agro-ecological conditions of land, technological enhancement and labour employed, the question of isolating the effects of such different production-factors is still debatable. Many scientists conceive productivity a relative concept and assess the factor productivity and try to detect the effects of such factors of production in a variety of ways. The production function and the regression analysis are common techniques to interpret the isolated effects of production factors. In the areas of under developed and developing economies as prevalent in the Brahmaputra Valley, it is assumed while calculating agricultural productivity that it is highly influenced by agro-ecological conditions of land rather than technology. As a result, agricultural productivity is more related to the physical factors of land. Thus, agricultural productivity refers to total production in its money terms per unit of cultivated land without showing the effects of the market prices. It is called land productivity (Singh, 1994; Sharma, 2003) and written as:

$$Yc = \left[\left(\sum_{i=1}^{n} Y_i A_i P_i\right) / \left(\sum_{i=1}^{n} A_i\right)\right],\ i = 1, 2, 3, \ldots, n\text{-th crops} \quad \ldots(1)$$

where Yc = calculated crop production per unit of cultivated land, that is defined here as agricultural productivity (Rs./ha), Y_i = yield of i-th crop (in kg/ha), A_i = area under i-th crops (in ha), and P_i = price per unit of quantity of production of a particular crop (in Rs./kg). Note that the crop- price is used as 'converter' of crop production to put all crops on their uniform scale considering them at their market importance (Singh and Chauhan 1977). The base year's crop-prices are used as constants to show changes in its real term from the early 1990s to early 2000s. This assumption is valid for Brahmaputra valley where there is not much influence of market prices on productivity with, resultantly, less differences in the relative prices among crops over time under consideration (Table 1).

TABLE 1. RELATIVE PRICES OF DIFFERENT CROPS AT THE TIME OF CROP HARVEST (1989 AND 1998)

Crops (1)	1989 Crop Prices (Rs./qtl) (2)	1989 Relative Prices (3)	1998 Crop Prices (Rs./qtl) (4)	1998 Relative Prices (5)
1. Rice	776.00	100.00	985.00	100.00
2. Wheat	850.00	109.58	1000.00	101.52
3. Maize	600.00	77.32	700.00	71.06
4. Sugarcane (Gur)	1200.00	154.64	1433.00	145.48
5. Potato	240.00	30.93	360.00	36.55
6. Pulses	1480.00	190.72	2050.00	208.12
7. Musterseeds	725.00	93.43	1500.00	152.28
8. Jute	280.00	36.08	450.00	45.68
Average price	--	99.08	--	107.58

Source: Monthly Price Bulletin for the year 1989 and 1998, Directorate of Agriculture, Government of Assam, Guwahati.

III

METHOD AND DATA COLLECTION

In order to describe the changes in agricultural productivity and impact of agro-ecological conditions of land on it, a regional frame of homogeneous agro-ecological conditions is constructed to delineate the agro-ecological zones of the study area. Following such criterion of the zonation, the entire Brahmaputra valley is divided into five agro-ecological zones, namely, the Lower Brahmaputra valley, Middle-Lower valley, central Brahmaputra Valley, Upper Northern and the Upper Southern plains of the valley (Taher, 1975 and 1986, Gopalakrishnan, 2000) (Figure 1). The administrative sub-division (i.e., smaller administrative unit than the district) is considered as an areal unit to show agricultural productivity pattern in general and also to visualise their changes within the agro-ecological zones.

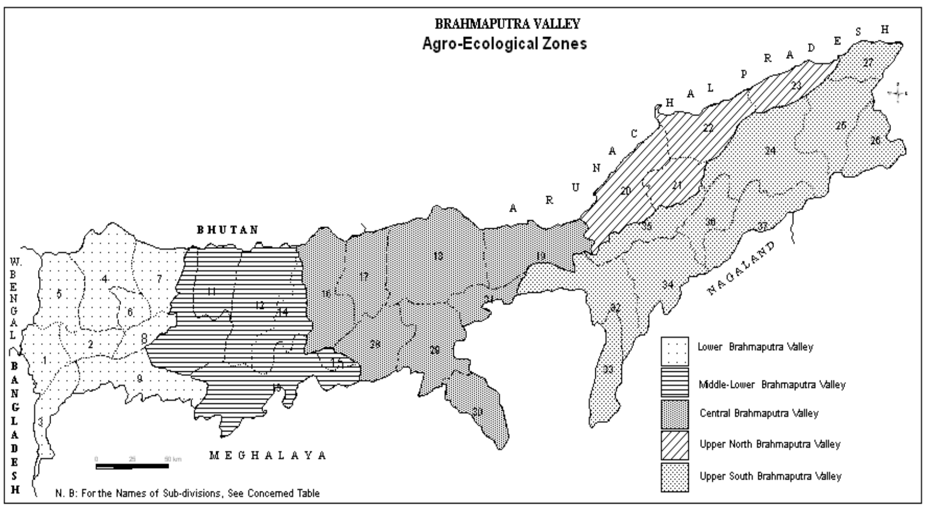

Figure 1

The changing pattern of agricultural productivity were visualised by considering two points of time: the period of early 1990s as base year (triennial average 1989-90, 1990-91 and 1991-92) and the early 2000s as current year (triennial average 1998-99, 1999-2000 and 2000-01). The cause-effect relationship was analysed to consider the variables relating to seed-fertiliser technology because they have significant impact on agricultural productivity while irrigation (an important attribute of modern technology in semi-arid areas of the country) was not included in the present analysis due to its insignificant impact on productivity in humid conditions of Brahmaputra valley.

There was negligible impact of green revolution technology on agricultural productivity prior to the 1990s. As a result, the areal variations in the agricultural productivity were considered under the direct control of agro-ecological conditions (Bhagabati *et al.*, 2001; Singh and Sharma, 2003). Therefore, ecology-effects were seen from the significance of differences in mean productivity among agro-ecological zones at base year's period of time. It is also argued that the intra-zone differences of productivity were created and increased over time because of the introduction of modern technology (Das 1995). Such intra-zone productivity differences are analysed by using 'coefficient of variation'. Overall, the effects of increasing use of fertilisers and high-yielding varieties (HYVs) on the changing productivity pattern were shown by applying 'multiple regression technique' as:

$$dY = a + b_1(dX_1) + b_2(dX_2) + e \quad \ldots(2)$$

where dY= productivity change (in Rs./ha) during the decade (1989-1992 to 1998-2001), dX_1= changes in fertiliser consumption (kg/ha), dX_2= changes in the percentage area under HYVs during the same period of time, b_1 and b_2 are coefficients, a is constant and e indicates error term of the function. Sub-division wise statistics of the crop area, crop yield, fertiliser used and the area under HYVs were collected from the Directorate of Statistics and Economics and the Directorate of Agriculture, Government of Assam, Guwahati for the years under consideration. The Gazetteers, Statistical Hand Books, Basic Statistics and other published relevant records of the Government of Assam, Guwahati were also used for the purpose.

IV

AGRICULTURAL PRODUCTIVITY PATTERN AND CHANGES THEREIN

Taking into account the crop-area, crop-yield and prices of eight principal crops of Brahmaputra valley as given in Table 1 and applying equation (1), the agricultural productivity (Rs./ha) was calculated for each sub-division for the early 1990s (1989-92) and early 2000s (1998-2001). The changing productivity patterns were visualised from the calculated data. Productivity pattern revealed that there were considerable variations in the areal pattern of agricultural productivity ranging from Rs. 3,952 per ha in the Barpeta-Bajali area of the Lower Brahmaputra to Rs. 12,271 per ha in Dhansiri area of the Upper-Southern part of valley during the time of base year. However, there was a record increase in productivity level as well as in changes therein during the 1990s as highlighted below:

(a) The productivity level rose by about 14.95 per cent from Rs. 6,250 per ha (1989-92) to Rs. 7,156 per ha (1989-2001) in the valley during the period of the application of seed-fertiliser technology with a marginal increase of about 8 per cent in crop intensity. The chemical fertiliser consumption in agricultural practices rose 172.85 per cent from 1.50 kg/ha (1989-92) to 4.12 kg/ha (1998-2001). The NSA under the use of HYVs increased by 3.67 per cent from 41.96 to 44.08 per cent during the same period of time (Table 2). Expansion of area under HYVs and intensification of the use of chemical fertiliser during the 1990s had fairly significant impact on crop intensification with a significant increase in the levels of agricultural productivity. Increase in the level of productivity might have expected more in such initial phase of application of seed-fertiliser technology in valley because of enough availability of agro- ecological land potential and, hence, agricultural production processes must follow the law of increasing marginal return to production factors. In spite of favourable land environment to produce more, increase in productivity appears to be slower (1.49 per cent annually) during the decade. There are many causes of slow increase in productivity and one of the implicit causes is the land tenure system, the *raiyatwari* system and the small size of operational land holdings (Das, 1984: pp.151-173). Subsistence mode of farming does not allow peasants to adopt modern technology intensively. They wish to apply technology but are not able to buy it because of their inelastic family income, low farm income and 'confined' decisions on their farm operations (Nath, 1983).

TABLE 2. VALUES OF DIFFERENT VARIABLES OF AGRICULTURAL PRODUCTIVITY FOR TWO POINTS OF TIME

			Agricultural productivity (Rs./ha)		Fertiliser use (kg/ha)		Area under HYV (per cent)		Change in productivity		Change in HYV area (per cent)
Sl. No. (1)	Sub-divisions (2)	Area in sq km (3)	1989-92 (4)	1998-01 (5)	1989-1992 (6)	1998-2001 (7)	1989-1992 (8)	1998-2001 (9)	Total (Rs./ha) (10)	Per cent (11)	(12)
1.	Dhubri	901.30	4208.06	5547.74	0.89	4.31	40.71	38.65	1339.68	31.84	-2.06
2.	Bilasipara	646.30	4208.06	4822.15	0.89	4.31	40.71	38.65	614.09	14.59	-2.06
3.	South Salmara	783.80	4227.96	4908.56	0.89	4.31	40.71	38.65	680.60	16.10	-2.06
4.	Kokrajhar	1839.00	4785.56	5265.39	1.22	4.65	52.11	39.02	479.83	10.03	-13.09
5.	Gossaingaon	1240.00	4102.18	4202.18	1.22	4.65	52.11	39.02	100.00	2.44	-13.09
6.	Bongaigaon	448.20	4789.24	4918.88	0.83	5.15	45.59	46.33	129.64	2.71	0.74
7.	Bijni	1115.00	4789.24	4669.24	0.83	5.15	45.59	46.33	-120.00	-2.51	0.74
8.	N.Salmara	551.90	4789.24	5289.24	0.83	5.15	45.59	46.33	500.00	10.44	0.74
9.	Goalpara	1673.00	5748.30	5528.00	1.66	6.33	22.12	40.00	-220.30	-3.83	17.88
10.	Barpeta	1930.00	3952.61	5157.37	0.41	4.49	66.77	48.12	1204.76	30.48	-18.65
11.	Bajali	1139.00	3952.61	5254.09	0.41	4.49	66.77	48.12	1301.48	32.93	-18.65
12.	Nalbari	2158.00	5572.40	4619.00	0.98	5.98	39.05	53.39	-953.40	-17.11	14.34
13.	Guwahati	2677.00	5238.93	7816.12	1.07	4.89	52.18	43.97	2577.19	49.19	-8.21
14.	Rangia	1085.00	2889.69	4722.42	1.07	4.89	52.18	43.97	1832.73	63.42	-8.21
15.	Pragjyotishpur	215.90	6063.15	7792.46	1.07	4.89	52.18	43.97	1729.31	28.52	-8.21
16.	Mangaldoi	1921.00	5524.79	6475.82	0.94	4.17	30.71	41.44	951.03	17.21	10.73
17.	Udalguri	1396.00	6390.33	6588.91	0.94	4.17	30.71	41.44	198.58	3.11	10.73
18.	Tezpur	3179.00	7371.91	8667.82	0.66	1.86	50.91	48.04	1295.91	17.58	-2.87
19.	Bisw Chariali	1920.00	7524.06	7651.48	0.66	1.86	50.91	48.04	127.42	1.69	-2.87
20.	N. Lakhimpur	1941.00	4559.48	6766.65	0.77	1.03	37.48	34.50	2207.17	48.41	-2.98
21.	Dhakuakhana	889.90	4559.48	2999.73	0.77	1.03	37.48	34.50	-1559.75	-34.21	-2.98
22.	Dhemaji	1547.00	4802.58	5020.99	0.13	0.33	31.07	24.04	218.41	4.55	-7.03
23.	Jonai	964.30	6448.00	4898.34	0.13	0.33	31.07	24.04	-1549.66	-24.03	-7.03
24.	Dibrugarh	2965.00	7036.60	7125.80	2.61	4.36	36.53	32.44	89.20	1.27	-4.09
25.	Tinsukia	1772.00	8177.89	8865.22	1.31	5.17	25.42	33.59	687.33	8.40	8.17
26.	Margherita	1081.00	5792.36	7789.23	1.31	5.17	25.42	33.59	1996.87	34.47	8.17
27.	Sadiya	775.00	7820.00	8757.57	1.31	5.17	25.42	33.59	937.57	11.99	8.17
28.	Morigaon	1426.00	5103.39	6837.28	3.12	9.50	54.34	77.02	1733.89	33.98	22.68
29.	Nogaon	1783.00	8220.79	8961.73	5.92	7.47	47.38	68.22	740.94	9.01	20.84
30.	Hojai	1057.00	9117.56	9985.69	5.92	7.47	47.38	68.22	868.13	9.52	20.84
31.	Kaliabar	665.80	9117.56	10242.71	5.92	7.47	47.38	68.22	1125.15	12.34	20.84
32.	Golaghat	1997.00	10078.53	17176.65	1.93	2.03	54.57	45.36	7098.12	70.43	-9.21
33.	Dhansiri	1002.00	12270.96	13206.72	1.93	2.03	54.57	45.36	935.76	7.63	-9.21
34.	Jorhat	1770.00	8818.99	10604.50	0.44	1.43	20.53	48.85	1785.51	20.25	28.32
35.	Majuli	1047.00	6704.69	7210.63	0.44	1.43	20.53	48.85	505.94	7.55	28.32
36.	Sibsagar	914.00	8715.62	10071.99	2.04	2.62	39.11	38.62	1356.37	15.56	-0.49
37.	Charaideo	1467.00	7798.06	8370.59	2.04	2.62	39.11	38.62	572.53	7.34	-0.49
Mean		--	6250.56	7156.46	1.50	4.12	41.96	44.08	905.89	14.95	2.13
Standard Deviation		--	2077.17	2786.87	1.48	2.15	12.06	11.46	1395.15	21.35	12.68
Coefficient of Variation (per cent)		---	33.23	38.94	98.42	52.14	28.73	26.00	154.01	142.78	595.88

Source: Directorate of Statistics and Economics, Government of Assam, Guwahati.

(b) There was a record increase (more than 20 per cent) in the agricultural productivity during the decade especially in some of the areas of Upper-Southern and Central parts of the valley (Figures 2, 3 and 4). Extremely high increase in agricultural productivity was recorded in the Upper Southern part of the valley especially in Golaghat sub-division (Rs. 7,098 per ha), followed by Jorhat (Rs.1,785 per ha), Sibsagar (Rs.1,356 per ha), Margherita sub-division (Rs.1,997 per ha) and Marigaon (Rs. 1,734 per ha) and in the central part of Brahmaputra valley in Guwahati (Rs. 2,577 per ha) and Rangia (Rs.1,833 per ha) sub-divisions (Table 2). Such obliterated pattern of productivity increase might be under the influence of the emergence of market centres acting as diffusion centres of agricultural innovations to their surroundings especially in these zones (Central and Upper-Southern parts) of the valley. The impact of agro-ecological conditions and isolation of the effects of seed- fertiliser technology in such areally differentiated scenario of agricultural development were, thus, tried to analyse in detail by considering inter- and intra- zonal variations of agricultural productivity.

V

INTER- AND INTRA-ZONAL VARIATIONS IN PRODUCTIVITY

The effects of agro-ecological conditions were quantitatively isolated to analyse the inter-zonal variations of agricultural productivity observed at the base year period. There are three recognisable agro-ecological scenarios in the inter-zonal productivity difference (Table 3). First, the zones, namely, the Lower Brahmaputra valley, the Middle-Lower and the Upper Northern Plains, are characterised as the most homogeneous agro-ecological zones, which have comparatively high annual precipitation (3000 to 5000 mm), high soil moisture, severe occasional floods and, resultantly, more soil erosion (NBSS and LUP, 1999). As a result, these zones had less inter-zonal differences in agricultural productivity in the early 1990s. Secondly, a different scenario of agro-ecological conditions in the Upper-Southern Plains of Jorhat- Moriani- Sibsagar areas with relatively less average annual precipitation (1,500 to 2,500 mm), less flood, less erosion and well-built up alluvial soils has created very high inter zone productivity variation (Rs. 3,694 per ha) with the earlier scenario in the valley. Thirdly, a scenario prevalent in the Central Brahmaputra valley of the moderate ecological conditions which has significant inter-zone variation (Rs. 2,685 per ha) between the Lower Brahmaputra plains and Upper Southern plains.

TABLE 3. INTER-ZONE DIFFERENTIAL CHARACTERISTICS OF AGRICULTURAL PRODUCTIVITY IN THE EARLY 1990S

Agro-ecological zones (1)	Lower Brahmaputra valley (2)	Middle Lower Brahmaputra valley (3)	Central Brahmaputra valley (4)	Upper Northern plain (5)	Upper Southern plain (6)
Lower Brahmaputra valley	0	-15.9	2668.8	464.9	3693.9
Middle Lower Brahmaputra valley		0	2684.7	480.8	3709.8
Central Brahmaputra valley			0	-2203.9	1025.1
Upper Northern plain				0	3229.0
Upper Southern plain					0

Notes: 1. The figures show values of mean zonal differences of agricultural productivity in Rs. per hectare. The values of relative changes are in percentages.

2. The negative values show as decreasing and positive as increasing inter- zonal differences in agricultural productivity.

Assuming that there is hardly any effect of ecology on productivity change over time (under the assumption of stable ecological conditions) and the changes in productivity within the zones during 1990s occurred because of technological enhancements, the intra- zonal productivity variations over time would show the effect of enhancement of seed-fertiliser technology. There are three valid observations drawn from Table 4.

(a) There is a marginal increase in mean productivity with decreasing degree of intra-zonal variability during the 1990s. The zones of Low, Middle-low and Central Brahmaputra valley appear to be under such characteristics of productivity change. The given figures of change in the areas of HYVs and fertiliser use of these zones showed that the fertiliser consumption increased in its almost all the sub-divisions, but a significant decline was recorded in many of the sub divisions situated in these zones. It means that the areal patterns of productivity became marginally more uniform and influenced by fertiliser use in these zones.

TABLE 4. INTRA-ZONAL VARIATIONS IN AGRICULTURAL PRODUCTIVITY

(Rs./ha)

Agro-Ecological Zones (1)	Years (2)	Minimum (3)	Maximum (4)	Difference (5)	Mean (6)	Standard Deviation (7)	Coefficient of Variation (per cent) (8)
Lower Brahmaputra	1989-1992	4102.2	5748.3	1646.1	4627.5	518.0	11.19
valley	1998-2001	4202.2	5547.7	1345.5	5016.8	436.3	8.70
middle Lower	1989-1992	2889.7	6063.1	3173.4	4611.6	1204.7	26.12
Brahmaputra valley	1998-2001	4619.0	7816.1	3197.1	5893.6	1499.9	25.45
Central Brahmaputra	1989-1992	5103.4	9117.6	4014.2	7296.3	1526.6	20.92
valley	1998-2001	6475.8	10242.7	3766.9	8176.4	1506.3	18.42
Upper Northern plain	1989-1992	4559.5	6448.0	1888.5	5092.4	911.0	17.89
	1998-2001	2999.7	6766.6	3766.9	4921.4	1529.3	31.07
Upper Southern plain	1989-1992	5792.4	12271.0	6478.6	8321.4	1834.7	22.05
	1998-2001	7125.8	17176.6	10050.8	9917.9	3136.0	31.62

Note: The figures show the agricultural productivity values in Rs. per hectare.

(b) Constant mean productivity with increasing intra-zonal variability persisted in the zone of Upper-North plain of humid and *tarai* conditions. There was a marginal shrink in its mean from Rs. 5092 per ha to Rs. 4921 per ha with a significant increase of about 13.2 per cent in areal variability within the zone from 17.89 per cent (1989-92) to 31.07 per cent (1998-2001) because of direct effect of flood, high rainfall and soil erosion on productivity. The catastrophic events explicitly create variability in the pattern of agricultural productivity within this zone of low productivity.

(c) Increasing mean productivity level with increasing intra- zone variability has been noticed in Upper Southern plain. A substantial decadal increase of about 20.0 per cent in the mean agricultural productivity in this zone of sub-humid conditions was marked with a significant areal variability of about 9.5 per cent from 22.05 per cent (1989-92) to 31.62 per cent (1998-2001). It is because a few sub-divisions within the zone have well-established market centres with properly connected rural roads in order to diffuse seed-fertiliser technology. As a result, the emerging pattern of agricultural productivity within this zone was more diversified while the market centres played a greater role in disseminating agricultural innovations. In such scenario of agricultural development, there seems to be an increase in income inequality among farmers and evolved areal variations in agricultural productivity as also highlighted by Polman and Freebairn (1973).

Relevant in this context is Binswanger's (1978a, 1978b) study of the use of tractor as multipurpose tool for agricultural development, which is valid in the scenario of substantial increase in productivity in the areas of Punjab–Haryana plains of semi-arid climatic conditions in India (Singh, 1994: pp.55-100). Such scenario of productivity increase has been visualised in Marigaon-Dibrugarh area where the fast growing market-economy and well-connected transport-routes influence the productivity. A section of farmers generate more agricultural surplus with their income-elasticity, and spend savings to buy a tractor of 20 HP for tillage, irrigation in dry winters and transportation purpose. The farms located in the close vicinity of market centres have the advantage of market accessibility costing less on transport to trade their farm products. Thereby, farm gate prices of the production become comparatively higher in its spatial context which fasten the growth in the productivity and production in the area. The question of 'appropriate' technology in such subsistence agriculture with humid agro-ecological conditions has to be answered in detail elsewhere. But it is a fact that the farmers economy at household level is more determined by the farm size. The heterogeneous environmental conditions of larger farm sizes determine the economies and diseconomies of farm production with diversifying crop pattern and providing a way to use intensively the modern techniques on the farm (Visser, 1999, Singh and Daimari, 2005). The landholders of larger size have also started gradually adopting the small- engine technology in this zone of Brahmaputra valley. As a result, there is a noticeable change in their cropping pattern from subsistence to semi-commercial, while semi-subsistence and dual-farmers of small farm size are also interested to use altered- oxen-drawn plough for increasing tillage area per worker and intensive seed-fertiliser technology in increasing crop-yield per hectare as concluded in the *Report on the Agricultural Survey of the Farm Production* conducted in the district of Jorhat, Assam (Gogoi 2003). Such technological enhancements create a scenario of production surplus and production input requirements that is more influenced by the road network and growing market forces in the area.

Market centres have point-concentrated effects and the development of road network has line-aligned features of productivity increase over space. If this common infrastructure is provided to an area for the agricultural development, it would enhance the overall productivity levels but would create areal variations in the productivity pattern (Singh, 1994). A fairly substantial increase in the use of chemical fertiliser and in the extension of areas under HYVs had been observed due to development in road-network and increasing role of central places, namely, the Jorhat, Sibsagar, Guwahati and Dibrugarh acting as diffusion centres of agricultural inputs in the valley. Such processes of intensification consequently widened the areal gaps in the distributional patterns of productivity.

Prioritisation of Production Factors

Regression analysis shows that the expansion in the area under HYVs has a significantly positive effect on increasing agricultural productivity especially in the areas of most flood-prone and humid conditions in the Low and Middle-lower zones of the Brahmaputra valley where resistant summer paddy HYVs like *Sali* paddy, IR-8, IN- 1, Jaya varieties are locally developed and popular among the peasants of Assam (Table 5). In the Central and Upper Southern plain zones where market centres and transport network help to disseminate the fertiliser use to the farmers, the effect of fertiliser intensification has prominently been observed. For example, Jorhat town has emerged as the major feeder centre of modern technology to boost the productivity in the Upper-Southern plains and Guwahati as a regional market centre of the Central Brahmaputra valley to play a significant role in increasing agricultural productivity in these areas. As a result, increase in one kilogram of chemical fertiliser in its use on one hectare of agricultural land increased fairly substantial amount of productivity of about Rs. 295 per ha in the zone of Upper-Southern plains. However, such rate of productivity increase was marked much lower (i.e., Rs. 116 per ha) in the Central Brahmaputra valley in spite of the diffusing effects of agricultural innovation through Guwahati market centre to its surroundings (Table 5). The error terms of productivity distribution were found less significant in these zones (Central Brahmaputra and Upper Southern plains) because of much higher coefficients of productivity variability as analysed in the preceding section. It means that enhancement of technology diversifies the productivity pattern with the increase in error term in its distribution. Consequently, the coefficient of determinant, R^2, becomes very low in such cases of increasing diversity in productivity pattern as also interpreted by Shiyani and Pandya (1998) for the agricultural development in the state of Gujarat.

TABLE 5. CHANGES IN AGRICULTURAL PRODUCTIVITY (dY) AS DEPENDENT VARIABLE REGRESSING WITH CHANGES IN THE USE OF FERTILISER (dX_1) AND IN PERCENTAGE CHANGE IN HYVS AREA (dX_2) AS INDEPENDENT VARIABLES IN DIFFERENT AGRO-ECOLOGICAL ZONES

Agro-ecological zones (1)	Constant (a) (2)	Coefficient (b_1) (3)	Coefficient (b_2) (4)	R^2 (5)	Standard Error (e) (6)
Lower Brahmaputra Valley (N=9)	3884.50	-897.40	22.213	0.5190	384.32*
Middle Lower Brahmaputra Valley (N=6)	12455.02	-2706.31	8.587	0.9400	379.74*
Cenntral Brahmaputra Valley (N=8)	439.336	115.84	12.110	0.2790	539.33**
Upper Northern Plain (N=4)	1051.66	244.28	3.321	0.1020	1080.61**
Upper Southern Plain (N=10)	2295.181	294.81	35.94	0.1380	1126.92**

** and *Significant at 10 and 5 per cent level, respectively.

VI

CONCLUSIONS

The techniques employed in the study offer insights into the changing pattern of agricultural productivity in Brahmaputra valley. In general, it may be concluded that the smoothness of general land use trends became fluctuating under the use of modern agricultural technology. As a result, intensification in agricultural practices has been started especially during the last decade of the twentieth century. However, the effects of enhancement of seed-fertiliser technology vary areally. There are four important deductions drawn from the present analysis.

(a) Application of seed-fertiliser technology has fairly good deal of impact on increasing agricultural productivity in the initial phase of agricultural development (i.e., 1990s) as it has been seen in the emerging productivity pattern in Brahmaputra valley. At the same time, it appears that a noticeably diversified areal pattern of agricultural productivity is coming up in the valley. It creates an areally-differentiated development scenario in the regional structure of agrarian economy. Such scenarios are emerging either due to intensification of seed-fertiliser technology in sub-humid Marigaon-Dibrugarh areas or due to the effects of natural calamities diversifying productivity pattern in the Upper Northern parts of the valley.

(b) Increasing use of chemical fertiliser has direct impact on the changing agricultural productivity pattern in semi-humid conditions of the valley and the expansion of cultivated land under HYVs increases the productivity marginally in the most humid parts of Lower as well as up to some extent in the Central areas in the valley.

(c) Increasing inter-zonal differences of agricultural productivity provide the evidence of the emergence of obliterated productivity patterns. They show the concentration of high agricultural productivity areas in the surrounding market centres.

(d) The questions pertaining to the application of 'appropriate' technology in humid tropical areas of the country like Brahmaputra valley of the subsistence-peasant agriculture, are still debatable and may be answered in applying an appropriate agricultural production function in which agro-ecological as well as technological factors are to be integrated implicitly for the analysis of observing the effects of these factors on the emerging areally-differentiated scenarios of agricultural development.

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REFERENCES

Barah, Bimal (2003), "*Population Characteristics and Agricultural Development in Jorhat District, Assam"*, Unpublished Ph. D. Thesis submitted to Department of Geography, North Eastern Hill University, Shillong, pp. 111-135.

Bhagabati, A.K., A.K. Bora and B.K. Kar (2001), *Geography of Assam*, Rajesh Publications, New Delhi, pp. 169-190.

Bhagabati, D. (2000), *Population Pressure on Land and Associated Problems in Selected Areas of Nalbari District, Assam*, M.Phil. Dissertation submitted to the Department of Geography, Gauhati University, Guwahati, pp. 50-87.

Bhalla, G.S. and Y.K. Alagh (1979), *Performance of Indian Agriculture*, Sterling Publications, New Delhi.

Bhalla, G.S. and D.S. Tyagi (1989), *Patterns in Indian Agricultural Development- A District Level Study*, Institute for Studies in Industrial Development, New Delhi, pp.1-10.

Bhat, L.S. and A.T.A. Learnmonth (1968), "Recent Contribution to the Economic Geography of India", *Economic Geography*, Vol. 44, No.3, pp. 189-202.

Bhatia, S.S. (1967), "A New Measurement of Agricultural Efficiency in Uttar Pradesh, India", *Economic Geography*, Vol. 43, No.3, pp. 244-260.

Binswanger, H.P. (1978a), *Economics of Tractors in South Asia*, Agricultural Development Council, New York and International Crops Research Institute for Semi-Arid Tropics, Hyderabad, India.

Binswanger, H.P. (1978b), "Induced Technological Change- Evolution of Thought", in H.P. Binswanger and V.W. Ruttan (Eds.) (1978), *Induced Innovation*, The Johns Hopkins University Press, Baltimore, U.S.A., pp.311-319.

Boserup, E. (1965), *The Conditions of Agricultural Growth,* George Allen & Unwin, London, U.K.

Boserup, E. (1981), *Population and Technology*, Basil Blackwell, Oxford.

Das, M.M. (1984), *Peasant Agriculture in Assam*, Inter-India Publications, New Delhi.

Das, M.M. (1995), *Land Holding Structure*: *A Problem in Peasant Agriculture in Peasant Agriculture in Assam*, Konark Publishers Pvt. Ltd., New Delhi, pp. 37-98.

Gogoi, K.K. (2003), Report on Farmers Survey in the Jorhat District, conducted by the Department of Geography, J. B. College, Jorhat, Assam.

Gopalakrishnan, R. (2000), *Assam - Land and People*, Omsons Publications, New Delhi, p. 132.

Goswami, P.C. (1988), *The Economic Development of Assam*, Kalyani Publications, New Delhi.

Kendall, M.G. (1939), "The Geographical Distribution of Crop-Production in England, *Journal of Royal Statistical Society*, Vol.102 (New Series), pp. 21-26.

NBSS & LUP (1999), *Soils of Assam for Optimizing Land Use*, NBSS Publ.-66, Soils of India Series, Nagpur, pp. 9-16.

Nath, V. (1969), "The Growth of Indian Agriculture- A Regional Analysis", *The Geographical Review* of India, Vol. IIX, (3), pp. 348-372.

Nath, L. (1983), *Growth and Development of Peasant Agriculture in Mangaldoi Region"*, unpublished M.Phil. Dissertation submitted to the Department of Geography, Gauhati University, Guwahati.

Polman and Freebairn (1973), *Food, Population and Employment- The Impact of Green Revolution*, Preager, New York, pp. 109.

Shafi, M. (1960), "Measurement of Agricultural Efficiency in Uttar Pradesh", *Economic Geography*, Vol.36, pp. 305.

Sharma, Bimal (2003), "*Changing Pattern of Agricultural Labour Productivity in Brahmaputra Valley"*, Unpublished M. Phil. Dissertation submitted to Department of Geography, North Eastern Hill University, Shillong, pp. 60-79.

Shiyani, R.L. and H.R. Pandya (1998), "Diversification of Agriculture in Gujarat: Spatio- Temporal Analysis", *Indian Journal of Agricultural Economics*, Vol. 53, No.4, October-December, pp. 627-637.

Singh S. and T.C. Daimari (2005), "Tea Production and Garden Size in the Upper Mrahmaputra Valley, India", *Asian Profile*, Vol. 33, No.3,pp. 269-279.

Singh S. and Bimal Sharma (2003)" "Determinants of Crop Intensity in the Assam Plains", *The Geographer*, Vol. 50, No.1, pp. 58-72.

Singh, Jasbir (1974), *The Green Revolution in India- How Green It Is*?, Vishal Publications, Kurukshetra.

Singh, L. Sunil (1998), "Role of Growth Centres in Agricultural Development in Manipur Valley", Unpublished Ph. D. Thesis, Department of Geography, North Eastern Hill University, Shillong, pp. 52-75.

Singh, S. and V.S. Chauhan (1977), "Measurement of Agricultural Productivity – A Case Study of Uttar Pradesh, India", *Geographical Review of India*, Vol.39, No.3, pp. 222-231.

Singh, S. (1994), *Agricultural Development in India- A Regional Analysis*, Kaushal Publications, Shillong.

Stamp, L. D. (1960), *Our Developing World*, Faber & Faber, London, pp. 104-110.

Taher, M. (1975): Regional Basis of Agricultural Planning in the Brahmaputra Valley, *The North Eastern Geographer*, Vol.8 Nos.1 and 2.

Taher, M. (1986), "Physiographic Framework of North East India", *The North Eastern Geographer*, Vol.18, Nos.1 and 2.

Visser, S. (1999), "Scale Economy Conditions for Variations in Farm Size", *Geographical Analysis*, Vol. 31, No.1, pp. 27-44.

Wharton, Jr. C.R. (1969), "Subsistence Agriculture - Concepts and Scope", in Jr. C.R. Wharton, (Ed.) (1969), *Subsistence Agriculture and Economic Development*, Aldine Publishing Co., Chicago, pp. 12-20.