Research Article

TRENDS IN THE FOOD CROP PRODUCTIVITY IN MICRO-AGROCLIMATIC ZONES OF JAMMU AND KASHMIR

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ABSTRACT

The present paper attempted to determine the trends in the food crop productivity in Jammu and Kashmir at agro-climatic zone level from 1980 to 2011. For the delineation of State into agro-climatic zones, altitude, precipitation-temperature regime, major crops are grown and agricultural productivity have been taken into consideration. The different map layers were prepared using suitable data base and methodologies. The superimposition of these map layers, viz., altitude zonation map, cropping land use map, productivity map and PT Index map resulted in the delineation of fourteen zones (five-climatic zones and nine agro-climatic zones). The productivity of the crops vary with the geo-climatic conditions and as a result of this, the productivity of rice (paddy) is highest in two zones of Jammu division (1J and 3J) and one zone of Kashmir valley (1K), while as productivity of maize is higher in zones of Jammu division (1J, 2J and 2'J) than Kashmir and similarly zone 2K is leading in the wheat productivity in Kashmir division and zone 3'J and 2'J are high productive wheat zones in Jammu division. The Ladakh division (zone L) is producing only wheat with the productivity of 17.26 q/ha (quintals/hectare). The productivity of all the three dominant crops doubled during these thirty years. On an average out of nine zones, the productivity in one zone is very high followed by three zones having high productivity; while as two zones each have medium and low productivity and one zone have very low productivity.

INTRODUCTION

The importance of climate in influencing land cover, *viz,* natural vegetation or land use, requires no emphasis. Climate dictates to a large extent what the natural vegetation is and which crops can be grown (Chapman and Brown, 1978). Climate is the most determining factor in the evaluation of agricultural potential and it defines the limits between which various crops can develop on the basis of soil and terrain composition (Verheye, 2010). An agro-climatic zone is a land unit, in terms of major climate and growing period that is climatically suitable for a certain range of crops (Balaguru, 2010). The problem of selecting the correct land for the cultivation of certain agriculture crops is a long-standing and mainly empirical issue (Kalogirou, 2002). Therefore many researchers have tried to prepare a standard framework for suitable and optimum agriculture land use. Agro climatology is the application of climatic concepts and principles to the design and management of sustainable agricultural systems (Gliessman, 1992). The agro climatic environment of a crop, land use or a farming system has physical, chemical and biological aspects. Thus, agro-climatic classification is an

extension of the climate classification keeping in view the suitability to agriculture. Agro-climatic zonation schemes are standard tools for prioritizing agricultural research because they offer relevant available information about the target environments (Corbett, 1996). The agro-climatic classification is an extension of the climatic classification keeping in view the suitability to agriculture. National commission on agriculture (1971) classified the country into 127 agro-climatic zones on the basis of three parameters, *viz*, temperature, precipitation and crops grown. The planning commission (1989) has divided India into 15 major agro-climatic regions on the basis of a commonality of agro-climatic factors like soil type, rainfall, temperature, water resources, etc. In this innovative approach, based on agro-climatic zones, an overall development profile of each region was formulated through an optimal mix of land stock management, crop production, animal husbandry, aquaculture, horticulture, forestry and agro-processing activities. UNESCO (1979) has developed a simple system for differentiating agro-climatic zones based on three major criteria: *Moisture regime, winter type* and *summer type*. The purpose of an agro-climatic zone map is to show the areas that are climatologically suitable for particular crops and to

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guide the work of planners and farmers (Francus, 2010). Agro-climate influences crop growth, yield and sustenance (Singh, 2011). Proper agro climatic zoning and seasonal climate forecasts are crucial elements in minimizing climatic risks (Sue et al, 2010). There is heterogeneity in the landscape, climate, soils, and crops grown in the Jammu and Kashmir state (Khan et al, 2001). Therefore generation of an agro-climatic zone map showing areas suitable for various agricultural alternatives in J&K using information on altitude, rainfall, temperature, soils and other relevant parameters is very important for the efficient land use planning and sustainable agricultural system.

Objective of the Study

To determine the trends in the food crop productivity in the micro agro-climatic zones of Jammu and Kashmir

Study Area

The state of Jammu and Kashmir constitutes northern most extremity of India and is situated between $32^o\,17'$ to $36^o\,58'$ N latitude and $73^o\,26'$ to $80^o\,30'$ E longitude. It falls in the great northwestern complex of the Himalayan Ranges with marked relief variation, snow-capped summits, antecedent drainage, complex geological structure and rich flora and fauna (Raina, 2002). The state is 640 km in length from north to south and 480 km from east to west. It consists of the territories of Jammu, Kashmir, Ladakh and Gilgit and is divided among three Asian sovereign states of India, Pakistan and China (Nandy, et al, 2001). The total area of the State is 2, 22, 236 km^2 comprising 6.93 per cent of the total area of the Indian territory including 78,114 km^2 under the occupation of Pakistan and 42,685 km^2 under China (Qazi, 2005).

MATERIALS AND METHODS

Materials

- Survey of India toposheets on 1:50000 scale were used for generating the base map of the study area and subsequently various map layers were generated.
- Data related to cropping land use variables has been obtained from concerned government and private departments.

Methods

Step 1: Identification of the Variables: The area under three major crops, *viz*, paddy, maize, and wheat have been taken for the accomplishment of the objective taken for the study.

Step 2: Proportional Standardized Mean and Composite Index: As the variables taken for the study are not equally important, therefore different weights have been assigned to these variables by the method of '*Proportional Standardized Mean*', that is, the weight assigned to one indicator is measured by calculating $\frac{\overline{x}}{\sigma}$ for any indicator.

Where, $\bar{X}$ is the average of the series of one particular indicator and σ is the standard deviation of same series

Then composite index was worked out by the following formula;

$$C.I. = \frac{x_1\dfrac{\overline{x_1}}{\sigma_1} + x_2\dfrac{\overline{x_2}}{\sigma_2} + x_3\dfrac{\overline{x_3}}{\sigma_3}}{\dfrac{\overline{x_1}}{\sigma_1} + \dfrac{\overline{x_2}}{\sigma_2} + \dfrac{\overline{x_3}}{\sigma_3}} \quad \cdots\cdots (i)$$

OR

$$C.I. = \frac{x_1 w_1 + x_2 w_2 + x_3 w_3}{w_1 + w_2 + w_3}$$

Step 3: Proportional Weightage Method: Since the productivity data is not available at agro-climatic zone level, therefore the productivity of districts has been used to generate the productivity database for the agro-climatic zones by using the '*proportional weightage*' method. The formula used for calculating the productivity is as under;

$$PZ_1Y_1 = A_1P_1 + A_2P_2 + \dots + A_nP_n \quad \dots\dots\dots(ii)$$

Where PZ_1Y_1 is the productivity of zone Z_1 for the year Y_1; A_1, A_2, ... A_n is percent area under districts D_1, D_2,..... D_n; and P_1, P_2, ... P_n is the productivity of the district's 1 to n

The levels of agricultural productivity have been worked out and the maps generated from survey of India (SOI) toposheets using Arc view 3.2a software have used to depict spatial variations in the variables taken for the study.

RESULTS AND DISCUSSION

Delineation of Micro-agro climatic zones of Jammu and Kashmir

An eclectic approach has been adopted in the research work to delineate the micro agro-climatic zones of the state. From the base map, different map layers, *viz,* physiography and Altitude zonation were prepared. Soil map was generated from Indian Council of Agricultural Research (ICAR) database. Precipitation temperature index map has been prepared by using the meteorological data from all the 54 stations located in the study area. Precipitation-temperature ratio (PT Index) has been calculated and a choropleth map has been prepared to devise PT zonation map. Cropping land use map was obtained by using the necessary data obtained from concerned departments. The different map layers obtained were superimposed to derive the agro-climatic zone map of the study area (Fig. 1) The classification of the zones was based on those of WMO-UNEP (1971-2000) and FAO (1996). The characteristics of the agro-climatic zones are presented in table 1.
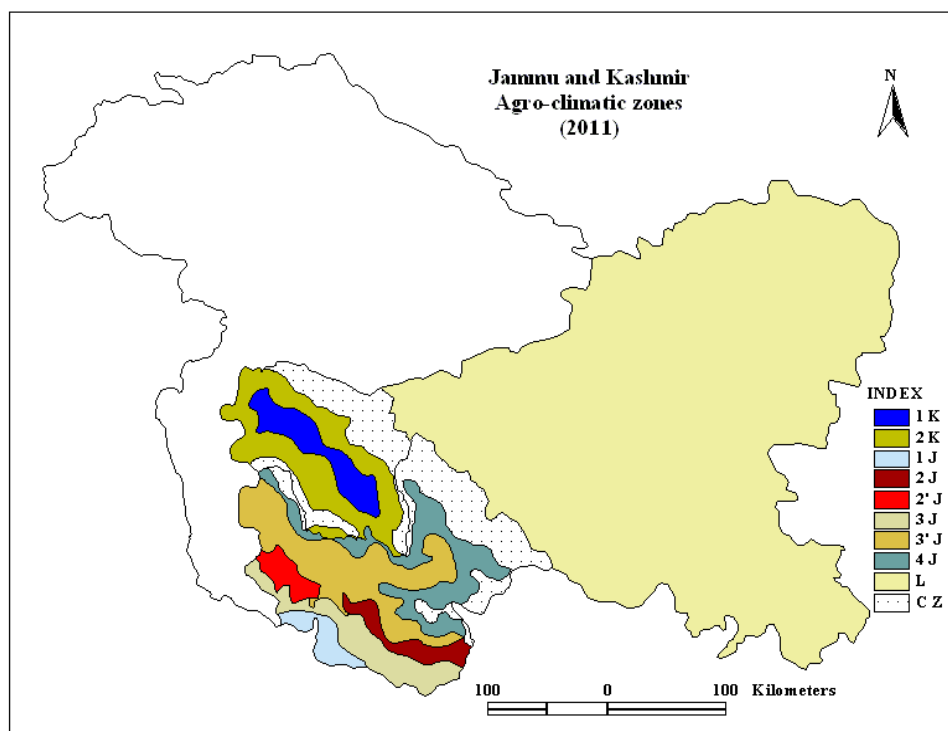
Fig 1 Agro-climatic zones of Jammu and Kashmir

Note: 'CZ' means '*climatic zone*'

Table 1 Characteristics of micro agro-climatic zones of Jammu and Kashmir

Zone Code	Altitude (in Meters)	Dominant Soil Group	Crops Grown	Area (in km²)	Productivity (Q/ha)			Average Precipitation (in mm)	Temperature(⁰C)	
					Rice	Maize	Wheat		M.Max	M.Min
1K	1000-1700	68, 81, 70	Rice, Maize, Mustard	4443.2	21.87	12.9	12.37	660	19.34	7.32
2K	1700-3000	58, 81, 18	Rice, Maize, Orchards	6045.21	20.58	14.63	14.01	967	16.62	5.92
3K	Above 3000	55, 18, 36	-	1000.94	-	-	-	1476	13.12	-0.23
3'K	Above 3000	17, 87, 58	-	4168.15	-	-	-	914	14.31	0.14
1J	Below 500	125, 124, 130	Basmati rice, Wheat,	1336.49	25.76	21.41	18.91	1386	28.09	17.39
2J	500-1000	115, 116, 86	Maize, Wheat, Rice	1570.67	21.03	18.97	18.87	1336	27.23	16.90
2'J	500-1000	116, 86, 115	Maize, Rice, Wheat	1166.68	21.12	17.03	19.09	1210	27.80	17.50
3J	1000-2000	116, 115, 125	Wheat, Rice, Maize	4131.09	22.99	14.9	18.42	1412	30.19	17.27
3'J	1000-1700	115, 86, 116	Maize, Rice, Wheat	7432.03	20.38	12.35	19.1	1592	25.48	14.84
4J	1700-3000	17, 116, 115	Maize, Wheat, Rice	5442.42	20.05	15.61	18.84	1387	22.32	9.43
5J	Above 3000	86, 17, 48	-	376.01	-	-	-	976	19.60	9.52
5'J	Above 3000	17, 115, 116	-	5843.8	-	-	-	1642	26.60	14.73
5"J	Above 3000	GG, 55, 17	-	440.91	-	-	-	1329	20.20	7.09
L	Above 3000	2, GG	Millets, Barley Wheat,	93531	-	-	19.39	157	11.11	-2.53

Note: "K, J, and *L*" represent *Kashmir, Jammu* and *'Ladakh Region'* and index of soil groups is given above

Brief Description of Agro-climatic Zones

1. Zone 1K: This zone covers the Jhelum valley floor in Kashmir Valley. Therefore being fertile, it is devoted to rice, maize and mustard cultivation. It receives adequate precipitation and the temperature is favourable for crop cultivation. The productivity of rice is more in this zone than zone 2K.

2. Zone 2K: This zone lies between 1700-3000m and therefore besides rice and maize, orchard cultivation is dominant in this zone. The overall agricultural productivity in this zone is neither too low nor too high. It receives more precipitation but less temperature than zone 1K.

3. Zone 3K and 3 K: These two zones lie above 3000m and therefore crop cultivation is not possible. These zones receive more precipitation especially in the form of snow. These zones cover substantial area of Bandipora, Ganderbal, Anantnag and Budgam districts of Kashmir valley.

4. Zone 1J: This zone has the lowest altitude (below 500m) and is basically an extension of Northern plains of India. It is very fertile and is known for *'Basmati rice'* cultivation. It receives sufficient rainfall and adequate insolation, therefore has highest productivity among all the zones.

5. Zone 2J: This zone has an altitude of 500-1000m. It is adjacent to zone 1J and it includes the areas of Kathua and Udhampur. Maize is dominant crop in this zone followed by wheat and rice.

6. Zone 2 J: This zone occupies the areas of Rajouri and Samba districts. It is a productive zone and all the crops grown in this zone have high productivity. This zone receives sufficient rainfall and insolation.

7. Zone 3J: This zone lies between 1000-2000m and occupies the areas of Kathua, Jammu, Rajouri and Samba districts. It is agriculturally productive and also has substantial area (4131km^2). Wheat, Rice and Maize are grown in this zone.

8. Zone 3 J: This zone occupies the areas of Udhampur, Reasi, Poonch, Rajouri, Ramban and Doda districts. It has an altitude of 1000-1700m and occupies an area of 7732 km^2. It receives maximum annual precipitation than other zones (1592mm/annum).

9. Zone 4J: This zone lies on higher altitude and therefore receives comparatively less insolation. It includes the areas of Kathua, Doda, Kishtwar and Poonch districts.

10. Zone L: This zone occupies the areas of Leh and Kargil districts. It lies above 3000m. Millets, Barley and Wheat is grown. Besides, it is famous for apricot cultivation. It occupies highest area (93531 km^2) among all the zones and being cold desert, it receives less precipitation (157mm/annum).

The temperature is also low in this zone with mean maximum of 11.11 C and mean minimum of -2.53 C.

11. Zone 3K, 3 K, 5J, 5 J, and 5 J: These five zones lie above 3000m altitude. Therefore these zones are not suitable for crop cultivation and so have been designated as climatic zones and not agro-climatic zones. Zone 3K and 3 K occupy the parts of Ganderbal, Bandipora, Kupwara and Budgam districts, while as zones located in Jammu division (5J, 5 J, and 5 J) occupy the parts of Kishtwar and Doda districts.

Trend of Food Crop Productivity in Agro-climatic Zones of Jammu and Kashmir

Agricultural productivity is the yield per unit of land. It is an important indicator of agricultural development. It depends both on the physical as well as socio-economic factors, *viz*, climate, soil, irrigation, per capita income, literacy, sex ratio and occupational structure etc. Since the productivity data is not available at agro-climatic zone level, therefore the productivity of districts has been used to generate the productivity database for the agro-climatic zones by using the *'proportional weightage'* method.

The productivity of all the major crops grown in the state has increased over the period of time and the trend of the major crops grown in different agro-climatic zones is discussed in the succeeding paras;

Table 2 Productivity of paddy in agro-climatic zones of Jammu and Kashmir

Zones	Productivity of paddy (quintals/hectare)							
	1980-81	1985-86	1990-91	1995-96	2000-01	2005-06	2011-12	Change (q/ha)
1k	8.84	9.72	10.96	12.57	14.73	16.84	21.87	13.03
2k	9.96	10.96	12.37	14.18	16.62	19.00	20.58	10.62
1 J	10.66	11.90	13.10	15.49	18.32	22.73	25.76	15.10
2J	8.48	10.24	11.44	13.28	15.55	17.99	21.03	12.55
2'J	8.70	9.57	10.66	12.01	13.91	16.22	21.12	12.42
3 J	9.28	10.83	12.04	14.01	16.40	19.50	22.99	13.71
3'J	8.80	10.26	11.17	12.86	15.08	17.29	20.38	11.58
4 J	9.05	11.02	11.79	13.45	15.61	17.42	20.05	11.00
L	-	-	-	-	-	-	-	-
Mean	9.22	10.56	11.69	13.48	15.78	18.37	21.72	12.50

Source: *Compiled by using data obtained from financial commissioner's office and formula (i), 2011*
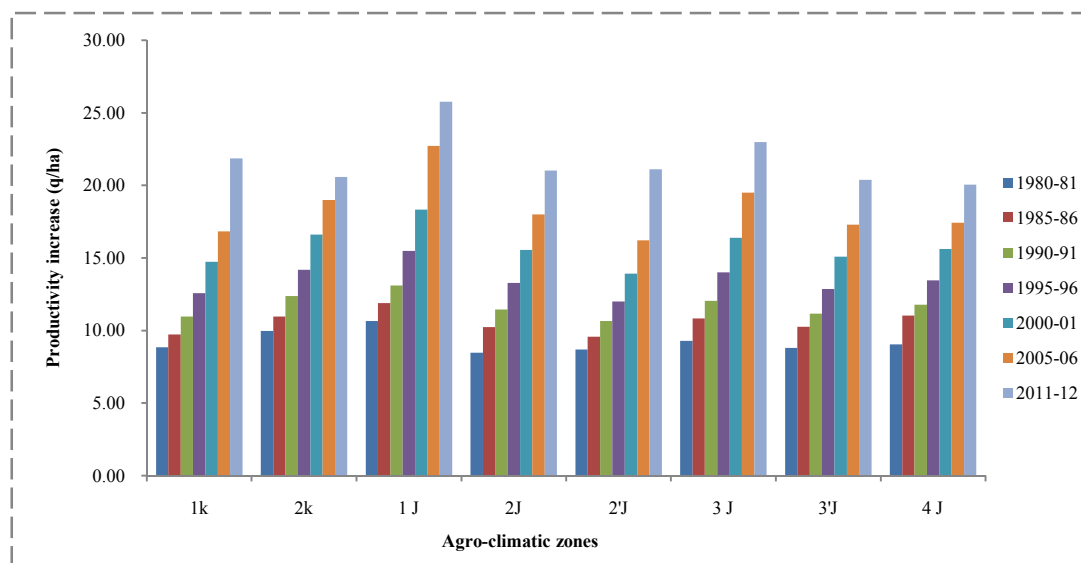

Fig 2 Trends in the paddy productivity in Jammu and Kashmir

The productivity of paddy in the agro-climatic zones of Jammu and Kashmir has increased from 9.22 quintals/hectare to 21.97 quintals/hectare, thus implies a total increase of 12.75 quintals/hectare during these twenty eight years [Table 2 and Fig 2].

The productivity has not increased much in the first fifteen years (1980-1995) and due to the use of improved seeds and fertilizers; it has increased at a fairly good rate in the last sixteen years (1995-2011).

Three zones out of the total in the state have more productivity increase than state average (12.75 q/ha). The highest productivity increase has been observed in zone 1J (15.10 q/ha), followed by 3J (13.71 q/ha) and 1k (13.03 q/ha), while as lowest increase is observed in zone 2k (10.62 q/ha) and 4J (11 q/ha) [Fig 3]. The productivity of rice is not possible in one zone of the state (*zone L*) because of the unfavourable geographical conditions for the growth of the crop.
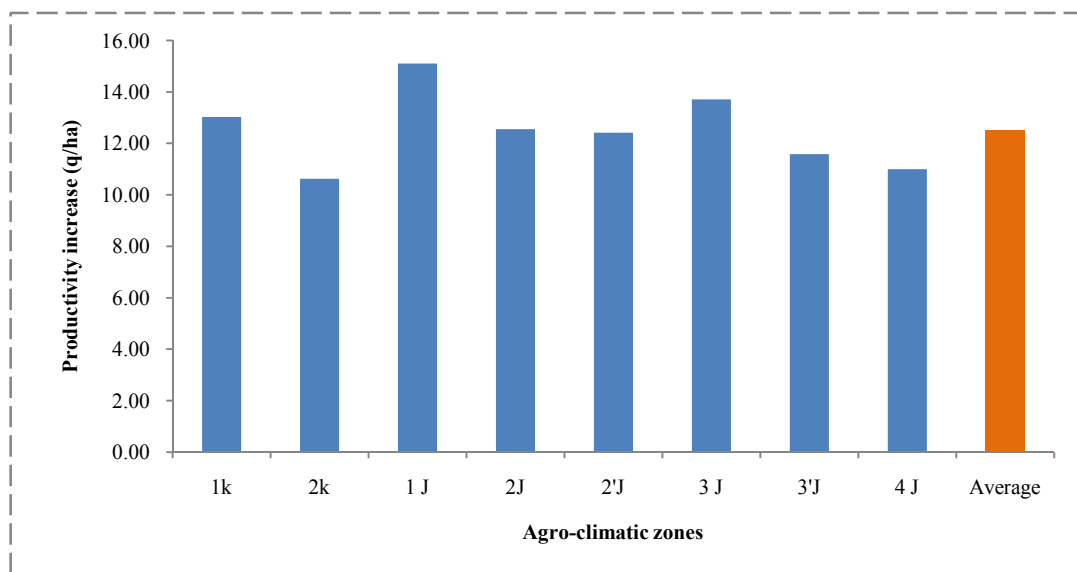
3J (5.51 q/ha). Four zones out of eight agro-climatic zones have low productivity increase than state average (Fig 5).

The wheat has also shown significant increase in productivity in all the agro-climatic zones of the state. It has increased from 7.41 quintals/hectare to 17.67 quintals/hectare, thus implies a total increase of 10.26 quintals/hectare (table 4 and Fig 6).

Like in case of paddy and maize, the productivity of wheat has also increased at a slower rate in the first fifteen years (1980-1995) than the last sixteen years (1995-2011) taken for the study.

Regional variations in the increase in productivity are observed across different agro-climatic zones of the study area. The highest increase is recorded in L (11.89 q/ha), followed by 2J (11.86 q/ha) and 2'J (11.79 q/ha), while the lowest is observed in 2k (8.34 q/ha) and1k (7.37 q/ha). Four agro-climatic zones have recorded low productivity increase than state average (Fig 7).

Fig 3 Paddy productivity growth in Jammu and Kashmir

The productivity of maize in all the agro-climatic zones of the state has increased. In absolute values, it has increased from 8.30 quintals/hectare in the year 1980 to 15.98 quintals/hectare 2011, thus implies a total increase of 7.67 quintals/hectare. Like paddy, the productivity has increased at a slower rate in the first fifteen years than the last sixteen years (table 3 and Fig 4).

Levels of Crop Productivity in Agro-climatic Zones

The determination and measurement of spatial variation of agricultural productivity is of vital importance for agricultural planning and development. In the present study, for the determination of the levels of crop productivity among the

Table 3 Productivity of maize in agro-climatic zones of Jammu and Kashmir

Zones	Productivity of maize (quintals/hectare)							
	1980-81	1985-86	1990-91	1995-96	2000-01	2005-06	2011-12	Change (q/ha)
1k	5.71	6.08	6.88	7.88	8.94	10.26	12.9	7.19
2k	6.46	6.88	7.79	8.92	10.13	11.62	14.63	8.17
1 J	11.12	12.15	13.25	14.56	15.74	17.81	21.41	10.29
2J	8.1	9.18	10.45	11.93	13.54	15.36	18.97	10.87
2'J	8.53	9.75	10.87	12.77	14.94	17.7	17.03	8.5
3 J	9.39	10.47	11.63	13	14.43	16.42	14.9	5.51
3'J	8.24	9.44	10.67	12.37	14.22	16.55	12.35	4.11
4 J	8.86	10.09	11.3	12.52	14.08	16.51	15.61	6.75
L	-	-	-	-	-	-	-	-
Mean	8.30	9.26	10.36	11.74	13.25	15.28	15.98	7.67

The highest increase in productivity among the various zones is recorded in 2J (10.87q/ha), followed 1J (10.29 q/ha) and 2'J (8.50 q/ha), while the lowest is observed in 3'J (4.11 q/ha) and

different agro-climatic zones of Jammu and Kashmir, the productivity of the three crops (Annexure I) have been taken.
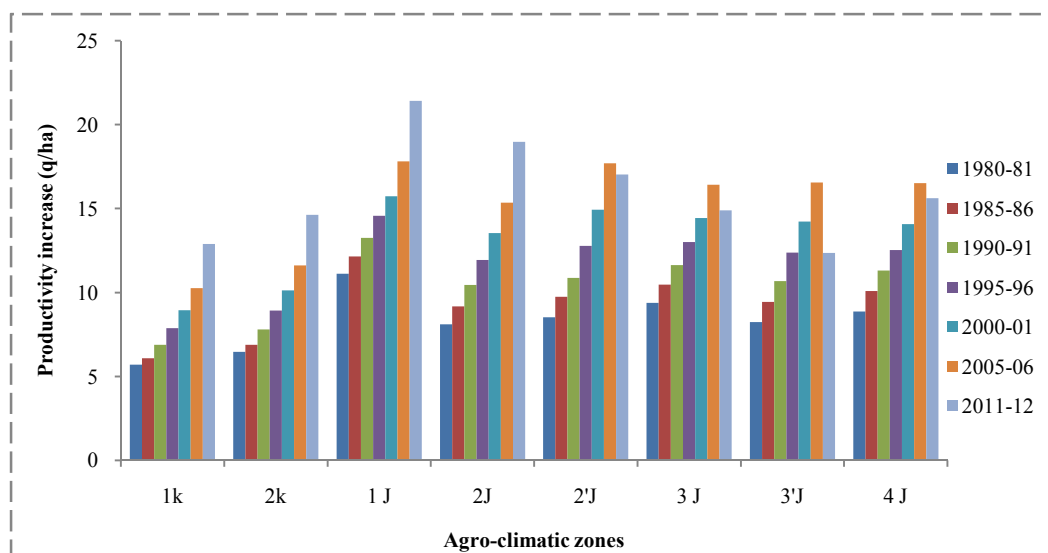
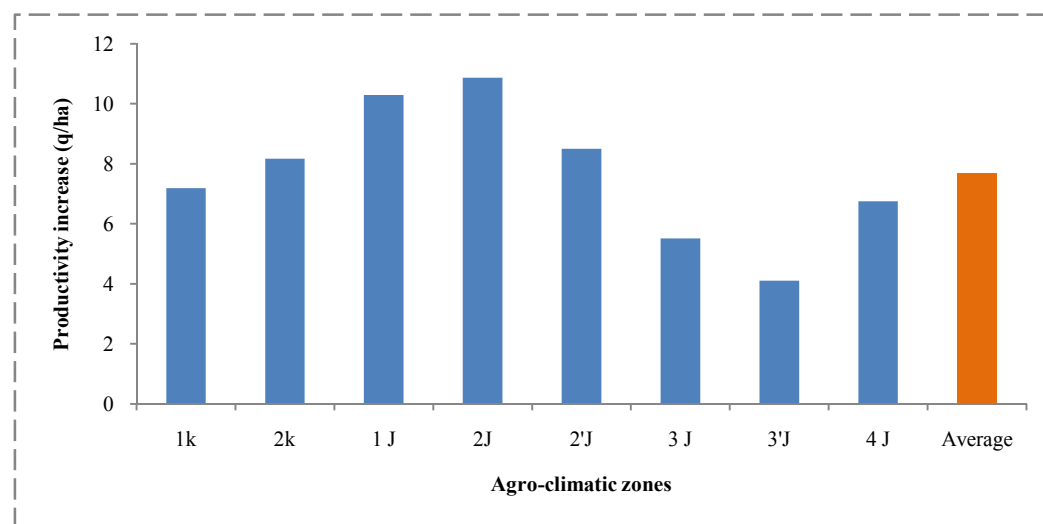**Fig 4** Trends in the maize productivity in Jammu and Kashmir

Fig 5 Maize productivity growth in Jammu and Kashmir

Table 4 Productivity of wheat in agro-climatic zones of Jammu and Kashmir

Zones	Productivity of wheat (quintals/hectare)							
	1980-81	1985-86	1990-91	1995-96	2000-01	2005-06	2011-12	Change (q/ha)
1k	5	5.62	6.44	7.46	8.45	9.82	12.37	**7.37**
2k	5.67	6.37	7.31	8.46	9.58	11.12	14.01	**8.34**
1 J	10.51	11.83	13.36	14.72	14.97	16.43	18.91	**8.40**
2J	7.01	8.04	9.78	12.04	13.64	15.45	18.87	**11.86**
2'J	7.3	8.55	9.98	11.65	13.71	16.3	19.09	**11.79**
3 J	8.22	9.4	11.03	12.97	14.07	15.81	18.42	**10.2**
3'J	7.61	8.78	10.05	11.65	13.25	15.6	19.1	**11.49**
4 J	7.86	9.16	10.04	11.63	12.7	15.01	18.84	**10.98**
L	7.5	8.59	9.775	11.3	13.51	15.725	19.39	**11.89**
Mean	**7.41**	**8.48**	**9.75**	**11.32**	**12.65**	**14.59**	**17.67**	**10.26**

Source: *Compiled by using data obtained from financial commissioner's office and formula (i), 2011*

Therefore the variables are;

1. Productivity of rice (x_1)
2. Productivity of wheat (x_2) in quintals/hectare
3. Productivity of maize (x_3)

As these three variables are not equally important, therefore different weights have been assigned to these variables by the method of '*Proportional Standardized Mean*' and then *composite index* and *composite indices* have been calculated.

Since the agricultural productivity is not uniform in the agro-climatic zones of the study area but exhibit great variations. The respective weights of the indicators chosen are: W_1= 11.57, W_2= 6.84 and W_3=5.30. Thus it is observed that the highest weight is shown for the productivity of paddy (11.55) and the lowest (5.30) is observed for productivity of maize, while as productivity of wheat is possessing medium weight (table 5).
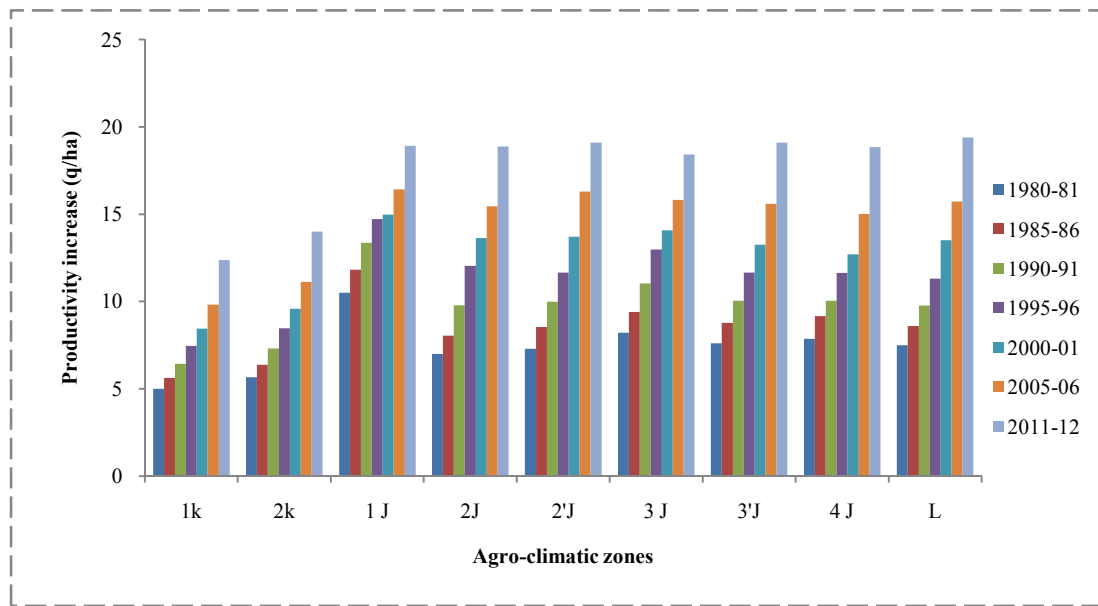
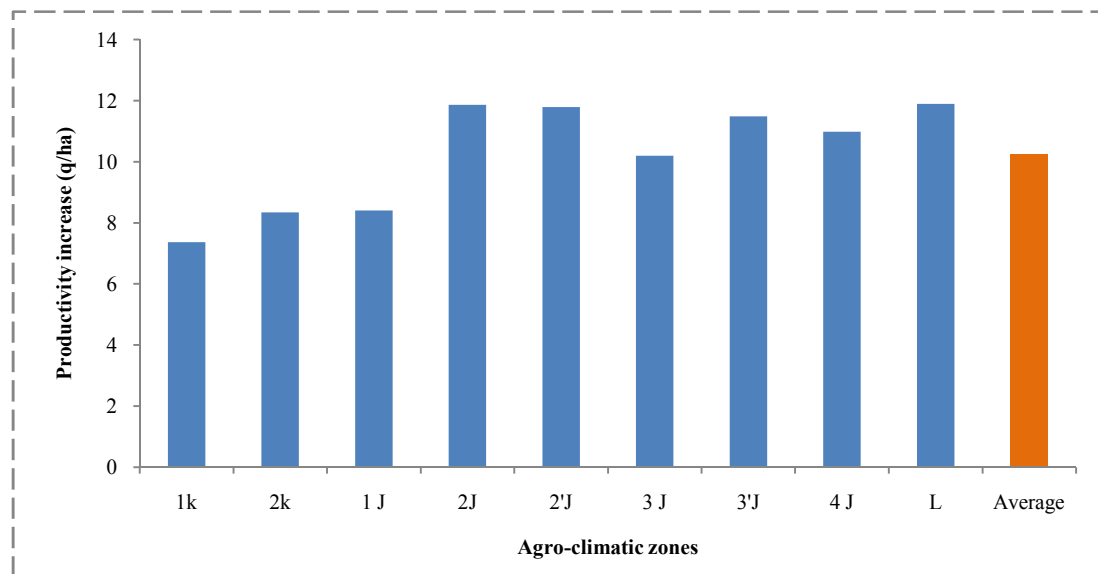**Fig 6** Trends in the wheat productivity in Jammu and Kashmir

Fig 7 Wheat productivity growth in Jammu and Kashmir

Table 5 Agricultural productivity indicators in agro-climatic zones

Zones	Paddy (X₁)	Wheat (X₂)	Maize (X₃)
1k	21.87	12.37	12.9
2k	20.58	14.01	14.63
1 J	25.76	18.91	21.41
2J	21.03	18.87	18.62
2'J	21.12	19.09	17.03
3 J	22.99	18.42	14.9
3'J	20.38	19.1	12.35
4 J	20.05	18.84	15.61
L	0	19.39	0
Total	173.78	159	127.45
Mean	21.72	17.67	15.93
S.D	1.88	2.58	3.01
Z-score (weight)	11.55	6.84	5.30
Total weight		23.70	

Source: *Compiled by using table in annexure I.*

The indices for all the districts have also been calculated by taking state as 100 (for average composite index of 17.69) as given below (table 6).

$$Indices = \frac{Composite\ index\ of\ any\ unit}{Average\ composite\ Index} \times 100 \dots\dots\dots\ (iii)$$

Table 6 Composite Index of Agricultural Development in Jammu and Kashmir

S.No.	Zone	Composite index	Indices
01.	1k	17.13	97
02.	2k	17.36	98
03.	1 J	22.82	129
04.	2J	19.87	112
05.	2'J	19.62	111
06.	3 J	19.87	112
07.	3'J	18.22	103
08.	4 J	18.71	106
09.	L	5.59	32
	Average	17.69	100

Source: *Compiled by authors using table 1.5 and formula (i) and (iii)*

The range of composite indices varied across the agro-climatic zones from the minimum value of 32 in 'Zone L' including the areas of Leh and Kargil to the maximum of 129 in 'Zone 1J'

including the areas of Jammu, Samba etc. which indicates that the former is highly advanced in the agricultural productivity and the latter is highly disadvantaged. The other zones which perform well in agricultural productivity are *2J, 2'J, and 3J* (indices value above 110). The other zones are comparatively less developed and have the indices value below 110 (table 7). The composite indices of agricultural productivity of different agro-climatic zones in the state are grouped into five categories which are produced in table 1.7and Fig 1.8. The zones in which agriculture is not possible are denoted by '*ANP*'.

Table 7 Ranking of zones in respect of agricultural productivity

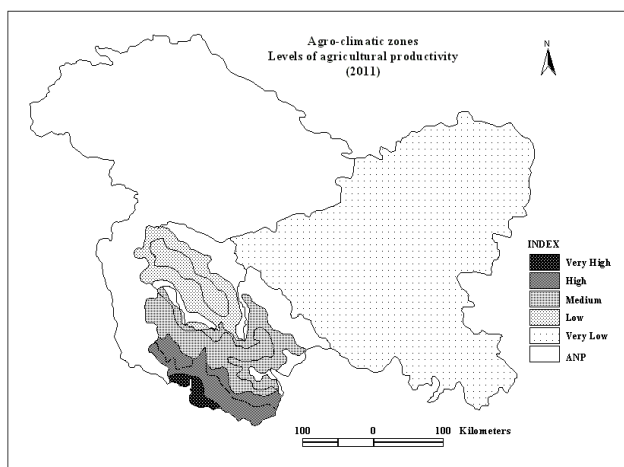| Index Value	Above 120	110-120	100 to 110	90-100	Below 90	Total
Category	Very high	High	Medium	Low	Very Low	
Name of zones	*1J*	*2J, 2'J, 3J*	*3'J, 4J*	*1k, 2k,*	*L*	
No. of zones	01	03	02	02	01	09
Percentage area to zones total	11.11	33.3	22.2	22.2	11.11	100

Fig 8

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