A Spatio-Temporal Analysis of Wheat Crop Diversification and Concentration in Baluchistan

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Abstract *- The purpose of this study is to examine crop diversification and crop concentration in Baluchistan, Pakistan during seven different periods of four years spells between1981 and 2009. The same has been pursued through measuring Crop Concentration Index (CCI) and Theil's / Shannon's Crop Diversification. The Herfindahl's index (also called Simpson index) and Theil's index (also called Shannon index) have been used for crop diversification. The Location Quotient measure has been used to determine crop concentration. Results show that similarities have been found in both (Herfindahl's and Theil's) diversification indices. The study reveals that cropping intensity is negatively and crop yield positively correlated with each other.*

Keywords *– crop diversification indices, crop concentration index, agro-ecological zones, cropping pattern, degree of diversification*

I. INTRODUCTION

Agriculture is an integral part of rural economy which provides employment and income. It has significant contribution towards the daily calorific intake of population, being the lifeline of economic growth of developing countries including Pakistan. Wheat is considered the major staple food crop of Pakistan. With reference to agricultural production, Punjab has the leading position among provinces of Pakistan while Baluchistan has the lowest rank (Burke, et al 2012). Due to low production of staple food crops, malnutrition and under nutrition are the basic causes of occurrence of diseases and poor socio-economic performance in Baluchistan province (Burke, et al., 2005& Huda, et al., 2008).

Baluchistan is located on the southwestern part of Pakistan, eastern part of Iranian plateau between 60.5° to 71.5°E of longitude and 24.8° to 32.3°N latitude. It consists upon 347 190 km²i.e. 34.7 million hectares (about 44% of the country's geographical area) and is the largest province but has sparsely dense population of the around 10.2 million (GoP 2008), with 19 persons per sq.km. Around 22% of population live in urban while 78%in rural areas. Agriculture is not practiced due to scarcity of irrigation water.About 1.1 million hectares (3%) is classified as forests, 60% rainfed, 40% irrigated and only about 1.5 million hectares (4%) is cultivated while 21 million hectares (60%) constitutes rangelands. Meteorologically, land above 850 m altitude is termed as hill/highland area while below that is termed as plain/lowland area, many flat valley bottoms between 1 000 and 2 200m altitude are surrounded by sloping rangelands that merge into mountain peaks reaching up to 3 600m. Coastal sand dunes of Makran sandy deserts of Chagai-Kharan as well as Sibi and Kacchi (Bolan, Nasirabad, Jaffarabad, JhalMagsi and Sohbatpur) are the vast lowland plains.

The temperature regimes vary widely from tropical to cool temperate. Mild summers to cold winters characterize the northern highlands while hot summer in lowlands. Mean minimum temperature closes to zero in winter while lowest minimum reaches up to -15°C in highland areas. Precipitation ranges from 250 to 350 mm dominated by western disturbances with residual influence of summer monsoons in the east make the climate of the province from hyper-arid to semi-arid. In the south-western desert, summers are hottest, with temperatures occasionally rising above 50°C whereas the annual rainfall ranges from 50 to 150 mm. Perennial water-supply in small quantities in streams is frequently common through small natural springs. The area

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physically consists of a widespread plateau of rough terrain divided into basins by mountains.

Wheat is the chief staple food crop occupying 56% share of total cropped area of the province (Burke, et al. 2012). It is cultivated under rain fed as well as in irrigated areas. The irrigated area of the province was about 93% and rain fed about 07% of total cultivated area of the province (GoP, 2000). Wheat is planted in mid-November to give higher yields (Khan, 1986; Subhan et al., 1999). Wheat was sown between late October and early November to produce comparatively better grain yields. Agriculture continues to be the mainstay of Baluchistan's economy with contribution of about 30% of the province during 2004-05 (Maliha et al., 2004). Agriculture in Baluchistan employs 67% of the labor force (Huda and Burke, 2012). Wheat produced in the province meets 60% of its requirement while the deficit is met with the help of other provinces. The Indus River also plays an important role in the production of wheat in its eastern districts, Jaffarabad and Nasirabad. Climate also plays an important role in crop diversification. The extensive objective of this paper is to scrutinize whether there is any kind of wheat crop diversification at district levels and to discover the key determining factors of its diversification. According to Ashraf and Majeed (2006), Baluchistan could be divided into six Agro-ecological zones, Highlands-I, Highlands-II, Sub-Highlands, Deserts, Plains and Coastal Zone.

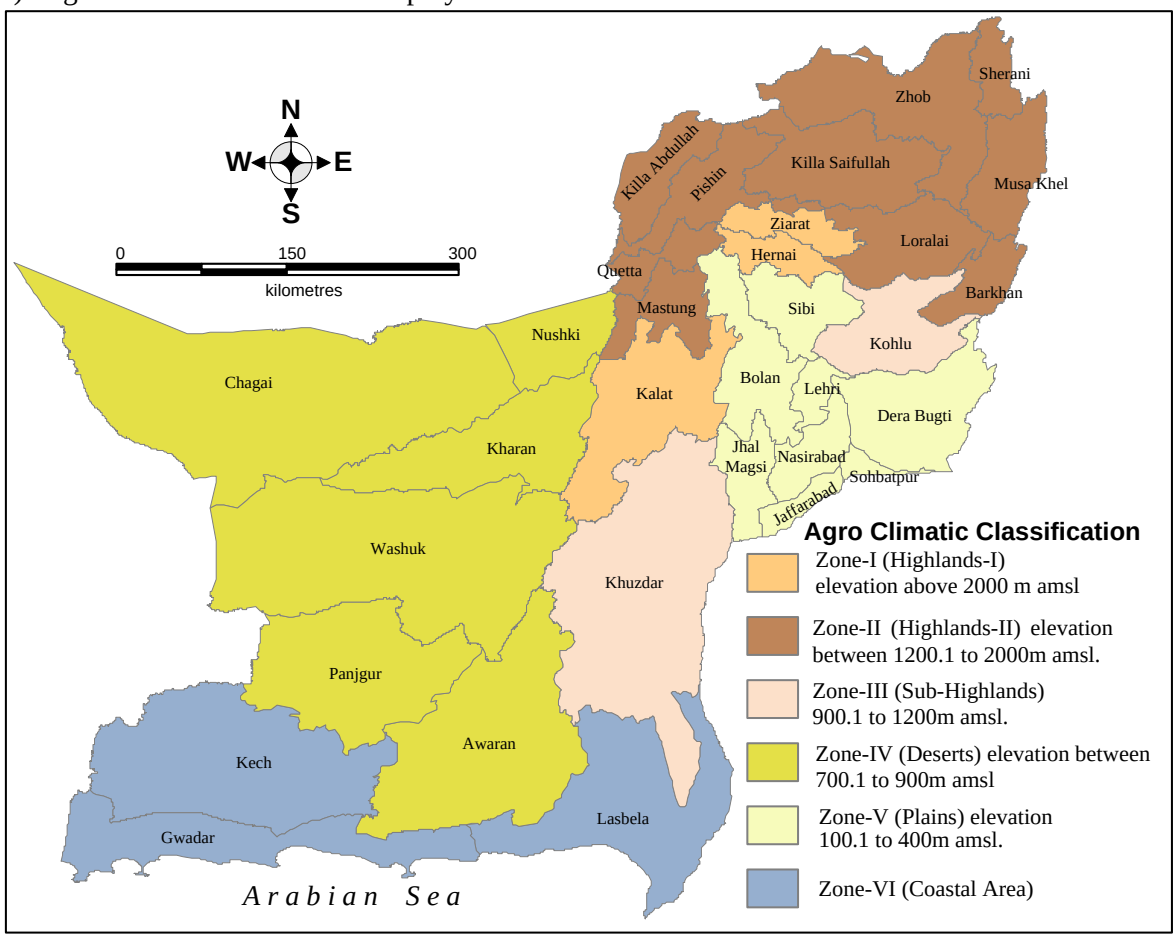

Fig. 1 depicts Agro Climatic Zones and Districts (Study Unit)

In less developed regions, agriculture is more reliant upon nature, consequently the risk of crop loss is actually elevated. Normally, lower the level of agricultural technology, greater the degrees of diversification and vice-versa. Crop diversification is one of the commonly recommended means for rural and agricultural development (Sajjad and Parasad, 2014; Let, 2011). Conceptually, it is opposite to crop specialization. It indicates shift from low value food crops to high value food/non-food crops, from subsistence farming to commercial farming or from single crop farming to multiple crop farming. The level of crop diversification largely depends upon technological development in the region and its agro

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climatic/socio-economic conditions. The purpose of this study was to examine wheat diversification using (crop) Diversity Index and improvement of food security of the rural people of Baluchistan.

II. METHODS

Data of wheat crop area and production for the period 1981-82 to 2008-09 of all 30 districts of Baluchistan has been obtained from Agriculture Census Organization of Pakistan. The data of climatic parameters viz., precipitation and temperatures has been obtained for the same period from Climate Data Processing Centre (CDPC), Pakistan Meteorological Department (PMD) Karachi. Administratively, Baluchistan had 30 districts namely, Khuzdar, Panjgur, Bolan, Kohlu, Kech, Lasbela, Chagai, Nushki, Loralai, Kalat, Washuk, Kharan, Gwadar, Quetta, Nasirabad, Harnai, Sibi, Pishin, Sherani, Zhob, Awaran, JhalMagsi, Jafferabad, Musa Khel, Barkhan, DeraBugti, KillaSaifullah, Ziarat, Mastung and Killa Abdullah. Bifurcation notification of two districts was not implemented till 2013.

2.1. Crop Diversification

For a study of Degree of Diversification, a number of methods are available in literature. A number of indices exist and several studies have been executed to calculate and compare different indices for distinct application purposes. Bhatia (1965) developed a simple formula by useful alternative index for determining the degree of diversification in cropping pattern in an area. Jasbir Singh (1976) modified Bhatia's formula and investigated spatial pattern of crop diversification in Haryana. Diversification indices are mathematical functions. These functions combine evenness and richness as a single measure. The most frequently used methods are Herfindahl index and Theil index. Herfindahl's index is also called Simpson index and Theil's index is also called Shannon index. Several analysts have proved that study of crop diversification is significant for analysis of agricultural productivity (Sati, 2012; Chakraborty, 2012;Barghouti, et al., 2003).

Herfindahl's/Simpson's DiversityIndex is defined as:

$$H = \sum_{i=1}^{n} p_i^2$$

Where $p_i = \frac{A_i}{\sum_{i=1}^{n} A_i}$ = Proportion of area under i^{th} crop.

Ai = Area under i^{th}crop and $\sum_{i=1}^{n} A_i$ =Total cropped area. The values lie within the set $\{x \mid x \text{ between } 0 \text{ and } 1\}$. Where 0 means perfect diversification and 1 means perfect specialization.

Theil's/Shannon's Diversity Index is defined as:

$$D = \sum_{i=1}^{n} p_i \log_e\left(1/p_i\right) \text{ or } D = \left(-\sum_{i=1}^{n} p_i \ln p_i\right)$$

It may also be written as $D = \left(-\sum_{i=1}^{n} \ln p_i^{pi}\right) = -\left(\ln p_1^{p1} + \ln p_2^{p2} + \ln p_3^{p3} + \cdots\cdots + n\, p_n^{pn}\right)$

$$= -\ln(p_1^{p1} \times p_2^{p2} \times p_3^{p3} \times \cdots\cdots \times p_n^{pn}) = -\ln\left(\prod_{i=1}^{n} p_i^{pi}\right) = \left(\frac{1}{\ln\left(\prod_{i=1}^{n} p_i^{pi}\right)}\right)$$

Mathematically both terms are equivalent to each other, therefore set of its values is similar and hence its result may be interpretedidentically.Here again p_i = Proportion of area under i^{th} crop and $\log_e$ is the natural logarithm. The set of values is $\{x \mid x \text{ between } 0 \text{ and } \log n\}$. Again 0 means perfect diversification and $\log_e$ n (or simply ln n) means perfect specialization.

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2.2. Crop Concentration

Variation in the density of crop or crops in a region or an area at a certain period of time or point is termed as Crop Concentration. The concentration of a crop in an area largely depends on its types of soil, terrain, moisture, climate, income and price, government policy, social factors and many others (Punithavathi, et al., 2012). Severalresearchers applied location Quotient method to perform degree of the Crop Concentration in particular study areawhich is most common method is the Location Quotient method to study Crop Concentration (Sajjad and Parasad, 2014; Chouhan, 1987; Hall and Tideman, 1967 & Singh, 1976).

$$CCI = \left(\frac{A_{i,j} / A}{\sum_{i=1}^{n} A_{i,j} / \sum A} \right)$$

$A_{i,j}$= Gross cropped area under ith spell in jth district, A = Gross cropped area in jth district in the entire study period,
$\sum A_{i,j}$= Gross cropped area in the ith spell in the province in the state,
$\sum A$ = Gross cropped area in the province during entire period, CCI = Crop Concentration Index.

The index value greater than unity means that district areal unit accounts for a share greater than it would have had if the distribution were evenly spread in the entire province and hence, the areal unit is adjudicated to have a concentration of large agricultural significance.

III. RESULT AND DISCUSSION

Simpson's and Shannon's Diversity indices have been calculated for the total study period 1981-82 to 2008-09 and seven spells of four years of period viz., 1981-82 to 1984-85, 1985-86 to 1988-1989, 1989-90 to 1992-93, 1993-94 to 1996-97, 1997-98 to 2000-2001, 2001-02 to 2004-05 and 2005-06 to 2008-09. The values of Herfindahl's/Simpson's diversity indices have been divided into three classes i.e., 0.0000 to 0.3333 as high diversity, 0.3334 to 0.6666 as moderate diversity and 0.6667 to 0.9999 as low diversity. 1.0000 considered as exceptional cases with complete evenness. The value of Theil's/Shannon's Diversity indices have also been split into three classes i.e., 1.3862 to 1.2425 as low, 1.2424to 0.9807 as moderate and 0.9806 to 0.0000 as high diversification. The values more than 1.3862 reveal perfect evenness. The analysis reveals that both diversity indices gave identical results for all spells. Hence, only Theil's / Shannon's Index have been depicted.

3.1. Crop Diversification

3.1.1. First and Second Spells (1981-82 to 1984-85 and 1985-86 to 1988-89)

Theil's/Shannon's diversity indices have been depicted for the first spell (1981-82 to 1984-85) and second spell (1985-86 to 1988-89) in Fig.1. During the first spell data was not available for ten (10) districts, viz., Awaran, JhalMagsi, Jafferabad, Musa Khel, Barkhan, DeraBugti, KillaSaifullah, Ziarat, MastungandKillaAbdullah.It is evident that in the first spell, there was no high diversification of wheat crop in any district, moderate in two (Khuzdar, Panjgur) while low in the remaining eighteen districts of the province.It has been found that Bolan acquired highest while Sherani and Zhob lowest measures with in low diversification. During the second spell data for 08 districts, viz., Awaran, JhalMagsi, Musa Khel, Barkhan, DeraBugti, KillaSaifullah, Mastung and Killa Abdullah were not available.During this spell 02 districts (Ziarat and Jafferabad) were found in high, 02 districts (GwadarandPanjgur) in moderate diversification zone while rest of the14 districts in low diversification zone. Harnai and Sibi revealed lowest, while Chagairecorded highest value within the low diversification zone.

3.1.2. Third and Fourth Spells (1989-90 to 1992-93 and 1993-94 to 1996-97)

Theil's / Shannon's diversity indices have been shown for the third (1989-90 to 1992-93) and fourth spells (1993-94 to 1996-97) in Fig.2. Data was not available for three (3) districts (Awaran, Ziarat and Killa Abdullah) for the third spell and for four (4) districts (Awaran, Gwadar, Ziarat and Killa Abdullah) during the fourth spell. It is apparent that during both spells no districts were found to have highest diversification. Six (6) districts viz., DeraBugti, Washuk, Kharan, Kohlu, Panjgur, Mastungand 12 districts viz., Barkhan, DeraBugti, JhalMagsi, Jafferabad, Bolan, Musa Khel, Loralai, Washuk, Kharan, Lasbela, Kech, Mastung emerged as a moderate diversification zone.
Twenty one (21) districts (Musa Khel, KillaSaifullah, Lasbela, Barkhan, Sherani, Zhob, Kech, Khuzdar,

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Kalat, Chagai, Nushki, Loralai, Bolan, JhalMagsi, Harnai, Sibi, Jafferabad, Nasirabad, Quetta, Pishin and Gwadar) have fallen in low diversification zone during the third spell while fourteen (14) districts (Nasirabad, Sherani, Zhob, Kalat, Panjgur, Pishin, Kohlu, Harnai, Sibi, KillaSaifullah, Chagai, Nushki, Quetta and Khuzdar) were found in low diversification zone during the fourth spell. Sherani and Zhob have been identified as highest while Jafferabad as lowest in low diversification zone during the third spell. Similarly, Gwadar has recorded lowest while Musa Khel highest value in low diversification zone.

Twenty one (21) districts (Musa Khel, KillaSaifullah, Lasbela, Barkhan, Sherani, Zhob, Kech, Khuzdar,

Kalat, Chagai, Nushki, Loralai, Bolan, JhalMagsi, Harnai, Sibi, Jafferabad, Nasirabad, Quetta, Pishin and Gwadar) have fallen in low diversification zone during third the spell while fourteen (14) districts (Nasirabad, Sherani, Zhob, Kalat, Panjgur, Pishin, Kohlu, Harnai, Sibi, KillaSaifullah, Chagai, Nushki, Quetta and Khuzdar) were found in low diversification zone during the fourth spell. Sherani and Zhob have been identified as highest while Jafferabad as lowest in low diversification zone during the third spell. Similarly, Gwadar has recorded lowest while Musa Khel highest value in low diversification zone.

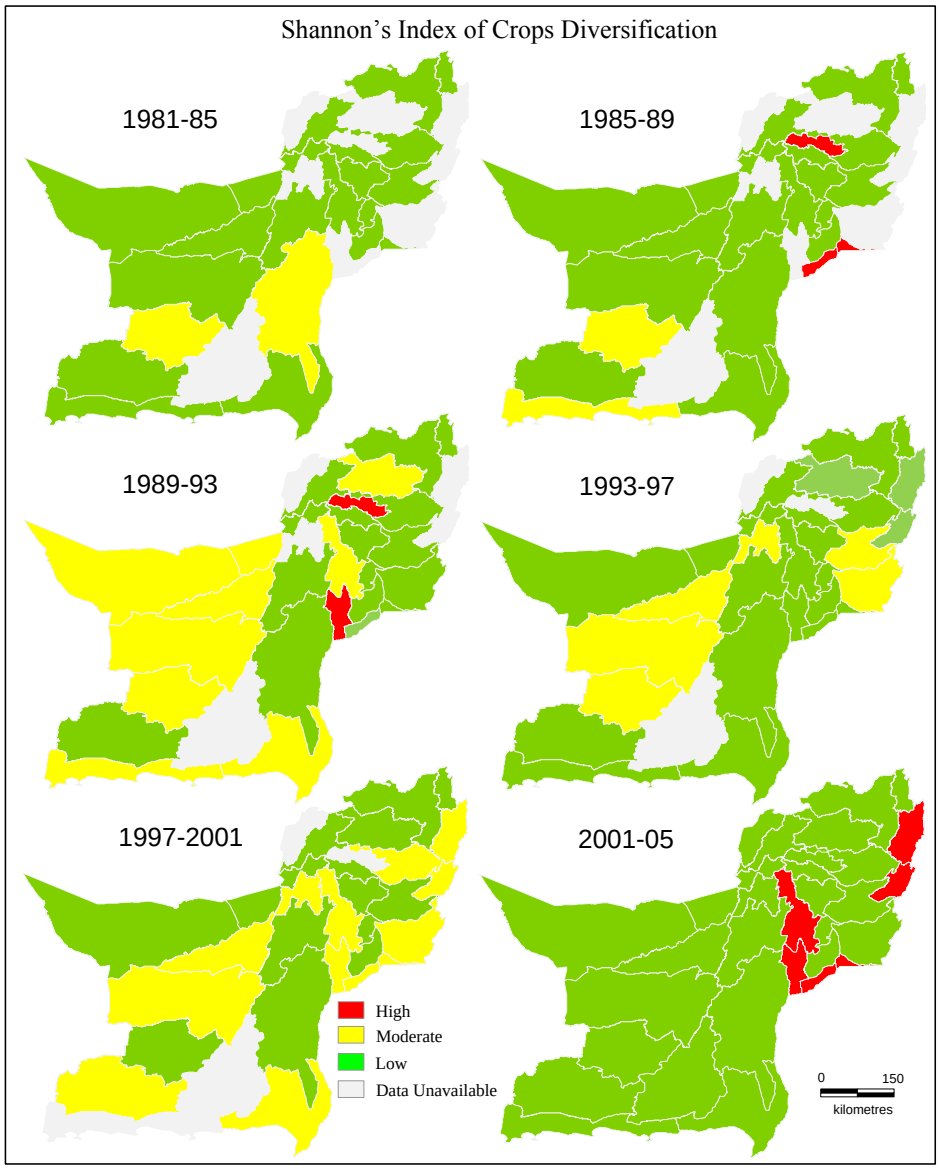

Fig.2 Shannon's Index of Crops Diversification

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3.1.3. Fifth and Sixth Spells (1997-98 to 2000-01 and 2001-02 to 2004-2005)

The fifth (1997-98 to 2000-01) and sixth (2001-02 to 2004-05) spells diversification have been depicted in Fig.3. Data for Awaran, Gwadar, Ziarat and Killa Abdullah was missing during the fifth spell, while during the 6th spell data for Gwadar was missing. It is apparent that in the fifth spell no district fell in high diversification while in the sixth spell no districts fell in moderate diversification zone. Barkhan, DeraBugti, JhalMagsi, Jafferabad, Bolan, Musa Khel, Loralai, Washuk, Kharan, Lasbela, Kech and Mastung have recorded moderate diversification while Nasirabad, Sherani, Zhob, Kalat, Panjgur, Pishin, Kohlu, Harnai, Sibi, KillaSaifullah, Chagai, Nushki, Quetta and Khuzdar have revealed low diversification zone during fifth spell.

Similarly, Jafferabad, Bolan, JhalMagsi, Barkhan and Musa Khel have fallen in high while Loralai, Washuk, Kharan, Awaran, Nasirabad, Ziarat, Pishin, Harnai, Sibi, Kech, Killa Abdullah, Panjgur, KillaSaifullah, DeraBugti, Lasbela, Chagai, Nushki, Kalat, Sherani, Zhob, Mastung, Kohlu, Khuzdar and Quettain low diversification zone during the sixth spell. During the fifth spell 12 districts were identified in moderate while 14 districts low in diversification zones. In the sixth spell five (5) districts were identified in a high while twenty-four (24) districts in low diversification zones.

3.1.4. Seventh Spell and Overall Study Period (2005-06 to 2008-09 and 1981-82 to 2008-09)

The seventh (2005-06 to 2008-09) spell and overall study period (1981-82 to 2008-09) diversification have been depicted in Fig.4. Data for Gwadar was missing during the seventh spell. It is apparent that in the seventh spell no district fell in high diversification zone. Awaran, PanjgurandJhalMagsi fell in moderate diversification; while Pishin, Killa Abdullah, Ziarat, Kohlu, Kech, Lasbela, Barkhan, Mastung, Harnai, Sibi, Sherani, Zhob, Jafferabad, Musa Khel, Washuk, Kharan, Kalat, Loralai, Chagai, Nushki, Quetta, KillaSaifullah, Nasirabad, DeraBugti, Bolan and Khuzdar fell in low diversification zone during the seventh spell.

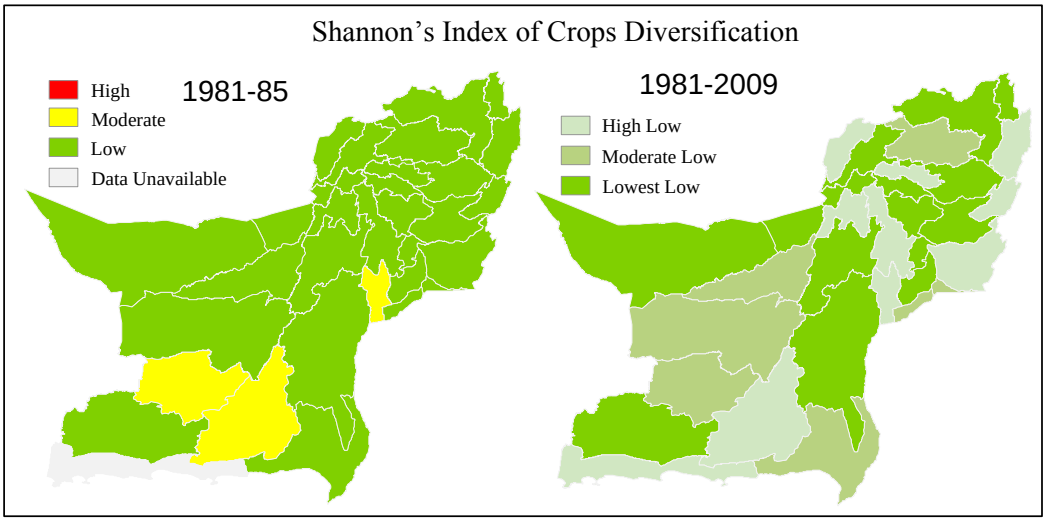

Fig.3 Shannon's Index of Crops Diversification

During the whole study period (1981-82 to 2008-09) all districts fell in low diversification zone. Micro analysis of entire study period revealed that ten (10) districts fell in highest low, six (6) in moderate low and rest of the fourteen (14) districts in lowest low diversification zones.

3.2. Crop Concentration

During the first spell Pishin, Loralai, Zhob, Kohlu, Kachhi, Nasirabad, Kech, Gwadar and Kalat districts during second spell Pishin, Loralai, Zhob, Sibi, Ziarat, Kohlu, Kachhi, Nasirabad, Tomboo, Gwadar and Kalat were most crop concentrated areas (Table.1). Quetta , Pishin, Loralai, Musa Khel, Sibi, Bolan, Jafferabad, Khuzdar, Kharan&Washuk, Kech and Kalat districts while Quetta, Pishin, Chagai, Musakhail, Barkhan, KillaSaifullah, Sibi, DeraBugti, Jafferabad, Mastung, Khuzdar, Kharan&Washuk, Kech, Panjgoor and JhalMagsi districts were the most crop concentrated districts during the third and fourth spells, respectively.

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Table 1. Crop Concentration Index

Time Spell / Districts	1981-82 to 1984-85	1985-86 to 1988-89	1989-90 to 1992-93	1993-94 to 1996-97	1997-98 to 2000-01	2001-02 to 2004-05	2005-06 to 2008-09	1981-82 to 2008-09
Quetta	0.746925	0.778928	1.057585	1.222479	1.354635	0.842708	0.944207	0.992495
Pishin	1.324893	1.343309	1.682458	1.347222	0.974699	0.329407	0.310898	1.044698
Killa Abdullah						2.606253	3.552602	3.079427
Chagai&Nushki	0.448612	0.385736	0.679053	1.22877	1.40148	1.349056	1.227433	0.96002
Loralai	1.149641	1.151044	1.302317	0.815317	0.718285	1.259313	0.696522	1.013206
Musa Khel			1.737413	1.605522	0.901144	0.799164	1.654756	1.3396
Barkhan			0.477912	1.355233	0.664127	1.070503	2.850984	1.283752
Zhob&Sherani	2.098889	2.141249	0.992647	0.534865	0.691177	0.488096	0.513197	1.065731
KillaSaifullah			0.597793	1.177795	1.61633	1.404288	1.71993	1.303227
Sibi&Hernai	0.991042	1.306542	1.185668	1.233383	0.954258	0.578846	0.882422	1.01888
Ziarat		2.013468	0.882264			1.841211	2.148221	1.721291
Kohlu	2.088299	1.588844	0.82594	0.89594	0.879926	0.396596	0.64663	1.046025
Bolan	1.596024	2.232719	2.100426		0.598237	1.010019		1.507485
DeraBugti		0.046825	0.246213	1.229349	0.393379	2.02105	2.439646	1.062744
Nasirabad	1.380044	1.17579	0.70366	0.699313	0.997634	1.229878	0.859165	1.006498
Jafferabad&Sohbatpur		0.848717	1.698422	1.682931	1.102348	0.667307	0.959116	1.159807
Lehri			0.48798	1.739203	1.465571	1.041431	1.800954	1.307028
Mastung			0.577791	2.31785	2.149533	0.738553	0.886615	1.334069
Khuzdar	1.022636	1.042129	1.25665	1.071591	0.986511	0.803325	0.883737	1.009511
Awaran						2.615771	3.543347	3.079559
Kharan&Washuk	0.543876	0.328018	1.069159	1.079509	0.881465	1.435575	1.397836	0.962205
Lasbela	0.229765	0.419701	0.347376	0.981329	1.047759	1.876329	1.675066	0.939618
Kech	1.314139	0.3973	1.044537	1.420991	1.003116	0.760157	0.999946	0.991455
Panjgur	0.406757	0.890651	0.520355	1.301992	1.487614	0.93263	1.291855	0.975979
Gwadar	3.631174	2.477095	0.592045	0.722101	0.35197			1.554877
JhalMagsi			0.285297	1.153091	1.072171	0.352375	3.513514	1.275289
Kalat	2.124691	1.504915	1.668337	0.708374	0.470761	0.388474	0.540436	1.057999

Quetta, Chagai, KillaSaifullah, Jafferabad, Bolan, Mastung, Lasbela, Kech, Panjgoor and JhalMagsi were the most crop concentrated districts during the fifth spell and Killa Abdullah, Chagai, Loralai, Barkhan, KillaSaifullah, Ziarat, Kachhi, DeraBugti, Nasirabad, Tomboo, Bolan, Awaran, Kharan&Washuk and Lasbela districts during the sixth spell. In the seventh and last spell, Killa Abdullah, Chagai, Musa Khel, Barkhan, KillaSaifullah, Ziarat, DeraBugti, Bolan, Awaran, Kharan, Washuk,Lasbela, Panjgoor and JhalMagsi were the most crop concentrated districts. The remaining districts had less than unity and therefore emerged as least crop concentrated districts.

Overall, during the entire study period Pishin, Killa Abdullah, Loralai, Musakhail, Barkhan, Zhob, KillaSaifullah, Sibi, Ziarat, Kohlu, Kachhi, DeraBugti, Nasirabad, Jafferabad, Bolan, Mastung, Khuzdar, Awaran, Gwadar, JhalMagsi and Kalat districts were the most crop concentrated districts while the remaining fell into least crop concentration category.

IV. CONCLUSIONS

This study was undertaken with a view of analysis regarding variability and diversification of wheat crop of Baluchistan during the seven different periods. The study revealed that in the first, second, fourth, sixth and

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seventh periods, low diversification of wheat crops dominated throughout the province. The analysis revealed that Crop Concentration is inversely proportional to (crop) Diversification. Hypothetically, the cropping intensity should be negatively and crop yield positively correlated with each other. During the fifth spell of the study period, moderate crop diversification was found to have spread over twenty-one districts due to country-wide drought epoch which was concentrated and highly diversified over eastern districts of the province during the sixth spell. This situation has revealed water as the key constraint to agriculture in the province and a high premium attached to water availability. Overall low crop diversification has indicated their illiteracy and negligible expertise regarding modern agricultural technologies.

It is suggested that output of existing wheat crop should be increased by adopting new technologies, high quality seeds and improving water preservation techniques. However, while doing this, the state mechanism should look after the interests of the poverty ridden masses who are still dependent upon this basic cereal crop.

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